AD-A041 274 ARMY ENGINEER DIV OHIO RIVER CINCINNATI F/G 8/6
OHIO RIVER BASIN COMPREHENSIVE SURVEY. VOLUME VI. APPENDIX E. G--ETC(U)
1965 M DEUTSCH, G D DOVE, P R JORDAN

UNCLASSIFIED NL

1 OF 3
AD A041274

VOLUME VI

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OHIO RIVER BASIN

COMPREHENSIVE SURVEY

APPENDIX E

Prepared by
U.S. Geological Survey,
U.S. Department of the Interior
in cooperation with Departments
of Agriculture; Army; Commerce;
Health, Education and Welfare;
the Federal Power Commission
and participating states.

GROUND WATER

U.S. ARMY ENGINEER DIVISION, OHIO RIVER-CINCINNATI, OHIO

1

Preliminary Survey
of

6

Ohio River Basin Comprehensive Survey.
Volume VI. Appendix E.
Ground Water.

GROUND-WATER DISTRIBUTION AND POTENTIAL in the OHIO RIVER BASIN

By

10

Morris Deutsch, George D. Dove
Paul R. Jordan, and Joe C. Wallace

11 1965

12 258p.

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

410 257

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INTRODUCTION

by

Morris Deutsch

The Corps of Engineers has been directed by Congress to prepare a comprehensive plan for the development of the water and related land resources of the Ohio River basin. The plan requires an analysis of the basinwide needs for streamflow control and use of water for domestic, municipal, agricultural, and industrial water supply; water-quality control; navigation; hydroelectric power; flood control and drainage; watershed protection and management; outdoor recreation; fish and wildlife conservation; and other purposes. A basic requisite for these analyses is a background of information and knowledge concerning the hydrology of the basin, especially the hydraulic characteristics of the streams and the hydrogeologic and chemical characteristics of its aquifers. The Geological Survey, one of the several federal agencies actively participating in formulating the comprehensive plan, was assigned to make a general appraisal of ground-water distribution and potential for its development within the Ohio River basin.

Purposes of the Ground-Water Investigation

Existing knowledge reveals that the ground-water resources of the Ohio River basin are large and have great potential for future development. The volume of ground water in storage in the aquifers throughout the basin is many times greater than the volume stored, or that can potentially be stored, in existing and planned surface reservoirs. Comprehensive basin planning therefore must consider where this resource may be tapped, its adequacy for various categories of use, and how it can be used and managed to best advantage.

This report, actually an appendix to the comprehensive plan, was prepared in accord with the following specific set of objectives:

1. To make a general appraisal, using currently available information, of the ground-water resources of the Ohio River basin.

2. To present the information in such a manner as to be readily usable as a general basis for long-range planning and as a guide for management and development decisions by public water-action agencies, and

3. To point out hydrologic factors that should be taken into consideration by the action agencies in formulating and implementing water-resource development plans.

Scope

The plan for the comprehensive survey included a broad, generalized appraisal of ground-water resources and potential throughout the Ohio River basin. Although much information is available concerning the ground-water conditions in specific areas as well as reports and maps summarizing various types of hydrologic data for several of the states, drainage basins, or physiographic regions, no systematic study of the entire basin had previously been made, nor uniform coverage provided. This report describes in broad, general terms the ground-water situation throughout the basin, the geologic units that comprise the chief aquifers, the major ground-water quantity-quality problems, and factors to be considered in the beneficial development of the basin's ground-water resources. Recommendations for more detailed studies, where deemed necessary, are included in the twelve sections of the report covering the sub-drainage areas of the basin.

The maps, prepared at the scale of 1:500,000, delineate areas of best, least, and intermediate potential for development of the ground-water resources. (Maps covering the Wabash and Cumberland River basins and the area designated as the Lower Ohio River drainage area were prepared at the scale of 1:1,000,000.) These maps may be used as a general guide for planning purposes. However, natural conditions generally vary within any area for which a development potential category is ascribed. The map scales, the lack of data providing uniform areal coverage, and the limitation of time made more precise delineation impractical.

Information on the quality of ground waters contained herein is not considered to be of sufficient scope for general planning purposes. The Federal Water Pollution Control Administration[1] currently is supporting more detailed studies by the Geological Survey on the quality and quantity of ground water and related streamflow in the Ohio River basin that will supplement the present report. These studies will be of value to FWPCA and other federal and state agencies in future activities regarding the establishment of water-quality standards, pollution abatement, and quality control.

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1. The Federal Water Pollution Control Administration was created by the Water Quality Act of 1965 and later transferred to the Department of Interior from the Public Health Service. As most of this report was prepared before the transfer, some references to the "U.S. Public Health Service" may be read as "Federal Water Pollution Control Administration".

Kinds of Information

The Ohio River Basin Comprehensive Survey covers in broad terms present and projected water and related land resource needs, but does not present plans for specific projects. This report, therefore, was not designed for application in specific engineering projects, nor does it emphasize the resource potential of one area versus another except as examples.

Comprehensive basin planning requires knowledge concerning not only where and how the ground-water resources can be used to greater advantage, but also where the resource offers little or no potential and may thus largely be disregarded in water-resources developments. For instance, the maps and text included herein show a tremendous potential for expanded ground-water development in the Great Miami-Whitewater and Little Miami River drainage areas in southwestern Ohio; whereas there is much less potential for large-scale development in the Cumberland basin. Similarly, within the Muskingum River basin the sub-drainage areas of the Walhonding and Tuscarawas Rivers can readily sustain further large-scale ground-water development, but the water-bearing formations in the unglaciated areas of the south-central and southeastern part of the basin offer little possibility for large-scale developments.

The greatest value that will likely be obtained from the ground-water maps are indications of ground-water availability as an alternative or supplemental source of water supply. These maps can be used to delineate areas where quantitative appraisals such as aquifer yield and pumping interference studies should be made of the potential ground-water supplies.

The following abbreviations are used throughout this report:

gpd, gallons per day
cfs, cubic feet per second
gpm, gallons per minute
cfs per sq. mi., cubic feet per second per square mile
mgd, million gallons per day
mg/l, milligrams per liter (equivalent to parts per million)

Nature of Available Ground-Water Coverage

Many types of reports on ground-water resources in the Ohio River basin have been published, ranging in detail from general state-wide summaries of widely varied scope to determinations of local aquifer characteristics. Many of these reports contain information that could be useful in planning for water-resources development, particularly in the planning of specific projects. The reports that are more detailed than the state-wide summaries, and that cover areas of county-size or larger (pl. 1) are listed in each sub-area report. The many reports on small areas, such as 15-minute quadrangles, have little relation to basinwide planning and therefore are not listed.

As plate 1 shows, coverage of the Ohio Basin by detailed reports is very sparse. General reconnaissance-type reports cover large parts of the basin, but basinwide planning for ground-water development should be based on uniform, basinwide ground-water coverage. Similarly, specific projects should be preceded by detailed coverage of the drainage area affected by the project. One of the difficulties encountered in the present study was that only one of the many available reports covers an interstate area. This made study of aquifers along the Ohio River valley especially difficult because of the fact that the river is the boundary of the various states along its course, after it leaves Pennsylvania.

In addition to reports on water resources, many geologic reports and maps contain information that is useful in the interpretation of ground-water conditions. The geologic information contained on the maps in the present report was adapted from the following geologic maps, and the geologic names used do not necessarily conform to the present standard nomenclature of the U.S. Geological Survey.

Amsden, T.W., Overbeck, R.M., and Martin, R.O.R., 1954, Geology and water resources of Garrett County: Maryland Dept. of Geology, Mines and Water Resources Bull. 14.

Cummins, J.W., 1959, Buried river valleys in Ohio: Ohio Div. Water, Rept. 10, Ohio Water Plan Inventory.

Geological Society of America, 1959, Glacial map of the United States east of the Rocky Mountains.

Geological Survey of Ohio, 1947, Geologic map of Ohio.

Goldthwaite, R.P., White, G.W., and Forsyth, J.L., 1961, Glacial map of Ohio: U.S. Geol. Survey Misc. Geol. Inv. Map I-316.

Illinois Geological Survey, 1961, Geologic map of Illinois showing bedrock below the glacial drift: Educational Series 7, plate 1.

Indiana Geological Survey, 1956, Geologic map of Indiana: Atlas of Mineral Resources of Indiana, Map No. 9.

Jillson, W.R., 1929, Geologic map of Kentucky: Kentucky Geol. Survey, ser. 6.

Kentucky Geological Survey, 1954, Geologic map of Kentucky.

Leverett, Frank, 1899, The Illinois glacial lobe: U.S. Geol. Survey Monographs, v. 38, pl. 6.

New York Geological Survey, 1961, Geologic map of New York.

North Carolina Department of Conservation and Development, 1958, Geologic map of North Carolina.

Pennsylvania Topographic and Geologic Survey, 1960, Geologic map of Pennsylvania.

Shepps, V.C., White, G.W., Droste, J.B., and Sitler, R.F., 1959, Glacial geology of northwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. G-32.

Tennessee Division of Geology, 1933, Geologic map of Tennessee.

United States Geological Survey, 1932, Geologic map of the United States.

Virginia Division of Mineral Resources, 1963, Geologic map of Virginia.

Wayne, W.J., 1958, Glacial geology of Indiana: Indiana Geol. Survey, Atlas of Mineral Resources of Indiana, Map No. 10.

West Virginia Geological Survey, 1932, Geologic map of West Virginia.

The surface-water records used herein are for the period of record available. Only the records for Ohio and Illinois are adjusted to a common period of record. All of the records used, however, were for a long enough period so that the comparisons made between dry-weather streamflows in different drainage areas are considered valid.

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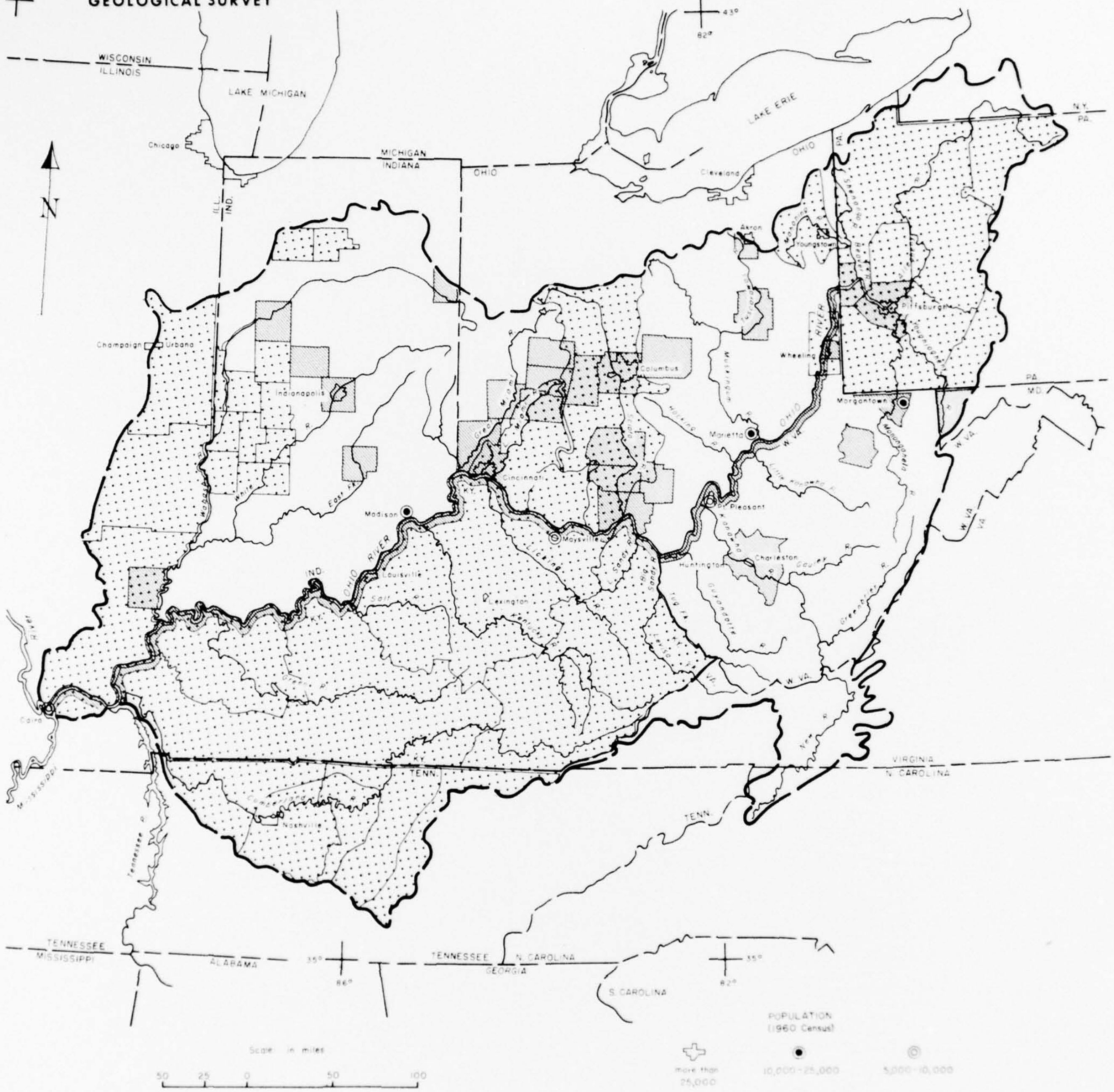

EXPLANATION

Areas covered by detailed reports.

Areas not covered by reports or covered only by state-wide summary reports, and in Ohio covered only by underground water resources inventory maps.

Areas covered by general, reconnaissance-type reports.

Note: Reports have been published for many areas smaller than county size, but such areas are not delineated on this map.

AREAS OF THE OHIO RIVER BASIN
FOR WHICH REPORTS
ON GROUND WATER INVESTIGATIONS
HAVE BEEN PUBLISHED
AS OF 31 DECEMBER 1964

PLATE 1

Methods of Investigation

Previous ground-water investigations, although extremely valuable and a great asset to the present investigation, generally covered much smaller areas based on political rather than hydrologic boundaries, such as counties or clusters of counties, and could not feasibly be adapted to an area as large as the Ohio Basin. In order to provide a "framework" of ground-water information for the 160,000 square mile area of the basin covered by the comprehensive survey, rapid-study techniques were used.

Available dry-weather or low-flow data were studied for indications as to which aquifers were discharging water to the streams, how much, and in what relative quantities compared to discharges to streams draining different aquifers. The dry-weather flows of the streams of the basin, not significantly affected by regulation, represent for the most part the overflow of ground water from subsurface aquifers. The yield of water per square mile of drainage area for each station where low-flow data are available is plotted on the sub-drainage area maps. This datum is technically termed the 90 percent duration flow or the flow exceeded 90 percent of the time, based on average daily flows and not necessarily for consecutive days. Because the predominant sources of this water are the aquifers feeding the streams during dry weather and not runoff from precipitation, the low-flow measurement in effect gives areal rather than point coverage. In other words, a flow of a stream at any given point is the end product of all the causative hydrologic factors upbasin; such as ground-water discharge, runoff, slope, precipitation, evapotranspiration conditions, use patterns, etc. A well log or pumpage record, on the other hand, provides hydrologic knowledge only at the location of the well.

Existing geologic mapping provided information concerning the areal extent of the principal water-bearing formations; and by correlating such information with low-flow and well-yield data, maps were prepared showing the sources of available ground water in the sub-drainage areas, along with the relative potential for development within and between aquifers.

For many areas of the basin detailed information on low flows, well yields, and aquifer characteristics are lacking or inadequate. In such cases, the ground-water potential was interpolated from conditions known to exist within the same formation or a similar formation from other areas. Available reports covering parts of such areas also were valuable guides for interpolations of this nature.

For the drainage areas north of the Ohio River, including the basins of the Allegheny, Beaver, Muskingum, Scioto, Great Miami, and Wabash, two maps were prepared; one showing the relative water-yielding capability of the unconsolidated glacial drift and alluvial sediments, and a second map giving the same information for the bedrock sources of ground water. When used in conjunction with each other, the two maps present an easy method of delineating areas with high potential for ground-water development. For example, in the Allegheny basin, sandstone of the Pocono Formation (a prolific water-yielding formation) is overlain by highly permeable glacial sediments. In addition, the Allegheny River and some of its tributaries flow directly over these aquifers (pls. 6 and 7) hence the potential for development is undoubtedly very great. For the drainage areas south of the Ohio River a single map is presented, showing the alluvial aquifers along major streams as well as the bedrock throughout the area.

Acknowledgments

The authors of this report are deeply grateful for the advice and assistance provided by the supervisors of the Geological Survey district offices covering the Ohio Basin states. The following District Chiefs or Chairmen of the Water Resources Division Councils and their staffs provided the project team with published reports, maps, and data from State and non-federal agencies engaged in cooperative water-resources investigations, in addition to providing technical review for the 12 sub-drainage area interim reports:

Illinois	William D. Mitchell	District Chief
Indiana	Malcolm Hale	District Chief
Kentucky	Floyd F. Schrader	Council Chairman
Maryland	John W. Wark	District Chief
New York	Ralph C. Heath	District Chief
North Carolina	Edward B. Rice	District Chief
Ohio	John J. Molloy	District Chief
Pennsylvania	Robert E. Steacy, succeeded by Joseph E. Barclay	Council Chairman
Tennessee	Joseph S. Cragwall, Jr.	District Chief
Virginia	James Gambrell	Council Chairman
West Virginia	William C. Griffin	District Chief

Special thanks are also due Frank A. Watkins, Jr., and Andrew M. Spieker of the Indiana and Ohio district offices who, because of their extensive knowledge concerning the hydrology of their areas, prepared the sub-drainage area reports for the Wabash and Great Miami-Little Miami River basins, respectively. In addition, the authors express their sincere appreciation to Rahat Ali Shamsi of the Water and Power Development Authority of Pakistan, who offered much helpful criticism and advice during the course of his review of the maps and major portions of the manuscript, and who co-authored the sub-area report covering the Guyandotte, Big Sandy, and Little Sandy River basins.

This project was conducted by the Geological Survey under the general supervision of Harry D. Wilson, Area Hydrologist, and William J. Drescher, Coordinator, Comprehensive River Basin Studies, Midcontinent Area. Morris Deutsch was project chief.

HYDROGEOLOGIC AND PHYSIOGRAPHIC SETTING

The Appalachian Mountains form the eastern divide of the Ohio River basin, and the major eastern tributaries all rise along the western flank of the mountains. The Allegheny River flows southward across the Appalachian Plateau (pl. 2), while the Monongahela flows northward to Pittsburgh where they join to form the Ohio. From Pittsburgh to Huntington, the Ohio flows generally southwestward through the center of the Plateau along a course roughly parallel to the Appalachian Mountains.

A narrow band along the northern portion of the Plateau in adjoining portions of New York, Pennsylvania, and Ohio, ranging from about 10 to 50 miles in width, is in the areas covered by continental glacial deposits, and these deposits are drained by the upper tributaries of the Allegheny, Beaver, and Muskingum Rivers. The Little Kanawha, Kanawha, Guyandotte, and Big Sandy Rivers flow northwestward to the Ohio across the Kanawha section of the Appalachian Plateau in West Virginia. Only the headwaters of the Kanawha River extend beyond the limit of the Appalachian Plateau; the New River rises in the crystalline rocks of the Blue Ridge and flows across the tightly folded rock strata of the Valley and Ridge province. In contrast, the Greenbrier River flows along a course parallel to the folds of the Valley and Ridge before it empties into the New River at Hinton, West Virginia.

Below Portsmouth, the Ohio flows generally westward for about 500 miles across the Interior Low Plateau province, almost to Paducah, where it enters the northernmost extension of the Gulf Coastal Plain. It flows along the north edge of the Coastal Plain for about 50 miles before emptying into the Mississippi River at Cairo.

Westward from near the divide between the Muskingum and Scioto River basins to the western divide with the upper Mississippi River basin, most of the area lying north of the Ohio River was covered by a succession of continental glaciers. This includes most of the area drained by the Scioto, Miami, and Wabash Rivers, and parts of the Muskingum, Beaver, and Allegheny Rivers.

The Licking and Kentucky Rivers flow northwestward from the Appalachian Plateau across the Lexington Plain of the Interior Low Plateau, while the entire lengths of the Salt and Green Rivers are within the Interior Low Plateau. The Cumberland River flows to the Ohio in a broad arc from the Cumberland Mountains in eastern Kentucky, through the Nashville Basin, and into the Ohio River at the edge of the Gulf Coastal Plain above Paducah.

Geology and Hydrology of the Bedrock Systems

The Ohio River basin is underlain by a wide variety of bedrock units ranging in age from Precambrian in North Carolina and Virginia to Cenozoic at the head of the Gulf Coastal Plain where the Ohio empties into the Mississippi River (pl. 3). With the exception of these two relatively small areas, however, Paleozoic rocks form the bedrock surface over the rest of the basin. Rock strata from all systems of the Paleozoic Era are present in the basin. Only the Cambrian rocks, which are present at the surface along the northwest flank of the Blue Ridge in the New River basin, are not shown separately on plate 3 because of the limitations of scale at which the map was prepared.

The bedrock units vary greatly in their hydrologic characteristics. Mississippian sandstone in the northwestern part of the Allegheny basin is capable of yielding very large quantities of water to wells; Ordovician and Mississippian limestones in Kentucky and West Virginia are the sources of numerous springs, whereas shales and siltstones of Permian and Pennsylvanian age that form the bedrock surface on both sides of the Ohio River between Wheeling and Point Pleasant yield little or no water to wells or springs.

General Structural Controls on the Basin Hydrology

The Appalachian Mountains from Pennsylvania to Tennessee form the divide between streams draining to the Ohio River basin and the Atlantic Ocean. In the northern portion of the Valley and Ridge Province in Pennsylvania, Maryland, and the easternmost part of West Virginia, drainage is to the Atlantic. Farther south, however, some of the tributaries of the Monongahela and Kanawha River flow between the folds of the rock layers in the Valley and Ridge. Examples of these are the upstream reaches of Tygarts Valley and Cheat Rivers, that flow northeastward along the folds before turning west onto the Appalachian Plateau and draining into the Monongahela River. The Greenbrier River, on the other hand, flows southwestward through parallel folds before it empties into the Kanawha River.

The streams flowing across the unglaciated sections of the Appalachian Plateau, especially those from the south, such as the Monongahela, Little Kanawha, Kanawha, Guyandotte, Kentucky, and Licking Rivers, have dissected the flat-lying rocks of the Plateau, giving the area a mountainous type of topography. Streams draining unglaciated portions of the Allegheny and Muskingum River basins have created a similar terrain in western Pennsylvania and eastern Ohio. Much of the dry-weather flow of these streams is gained from springs discharging from valley walls above the rivers.

The Pine Mountain thrust fault forms the divide in the headwaters areas between the Kentucky and Cumberland Rivers. North of the fault, the streams draining the Plateau drain to the middle portions of the Ohio River, whereas south of the fault, the drainage is westward into the Cumberland basin.

Two important geologic structures, the Cincinnati Arch and the Nashville Dome, are major features in the west-central part of the Ohio River basin that exert strong controls on hydrologic conditions. The Ordovician rocks, the oldest rocks that crop out within the basin west of the Valley and Ridge Province, are exposed at the surface of these structures. These rocks are composed predominantly of shales and limestones. The oldest strata, or lowest stratigraphically, are the thick limestones underlying the Blue Grass region of Kentucky. These rocks comprise an important aquifer. In the Great Miami basin of Ohio and the central Cumberland basin of Tennessee, Upper Ordovician strata, composed chiefly of interbedded shales, siltstones, and limestones, are exposed at the surface, and generally form poor aquifers.

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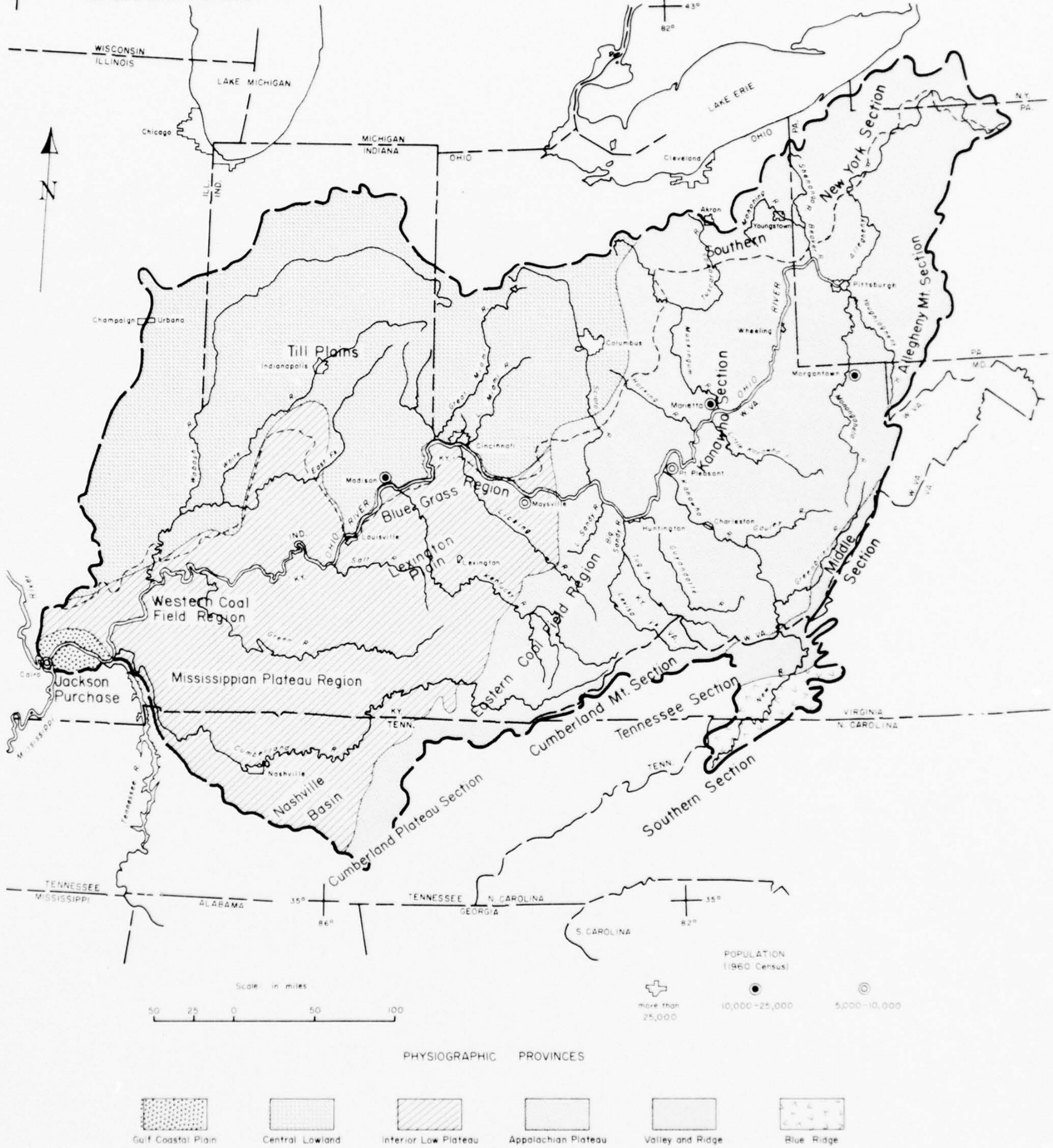


Adapted from:

Fenneman, N.M., 1938, Physiography of eastern United States: New York, McGraw-Hill Book Company.

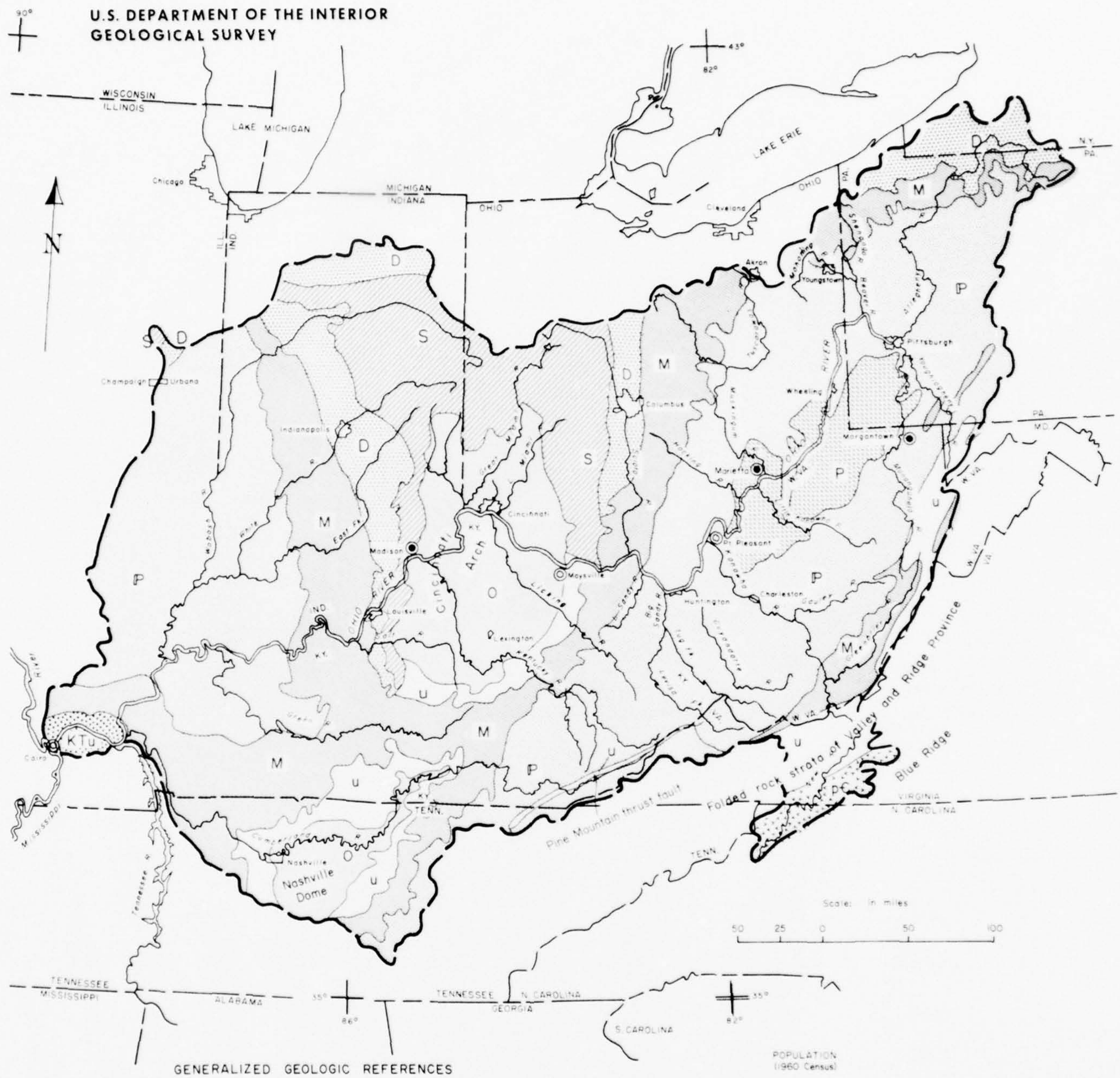
Hendrickson, G.E., 1958, Summary of occurrence of ground water in Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-10.

Raisz, Erwin, 1957, Land forms of the United States: Map, sixth revised edition.

Southern limit of Continental Glaciation

OHIO RIVER BASIN
PHYSIOGRAPHIC REGIONS

PLATE 2



GENERALIZED GEOLOGIC REFERENCES

MESOZOIC
- KTu — Cretaceous and Tertiary, undivided

PALEOZOIC
- P — Permian and Pennsylvanian
- ℙ — Pennsylvanian
- M — Mississippian
- D — Devonian
- S — Silurian
- O — Ordovician
- u — Paleozoic rocks, undivided*

- pЄ — Precambrian

POPULATION
(1960 Census)

more than 25,000 — 10,000–25,000 — 5,000–10,000

*Includes Cambrian through Mississippian rocks in Valley and Ridge Province; Upper Ordovician, Silurian, and Devonian rocks along southern rim of Cincinnati Arch; Silurian, Devonian, and Lower Mississippian rocks around Nashville Dome, and Devonian and Mississippian rocks along Pine Mountain thrust fault.

Adapted from: U. S. Geological Survey, 1932, Geologic map of the United States.

OHIO RIVER BASIN
BEDROCK SYSTEMS

PLATE 3

Both the Cincinnati Arch and Nashville Dome are flanked by Silurian and Devonian rocks. In Ohio and Indiana, the Silurian rocks forming the flanks of the Cincinnati Arch are important aquifers consisting principally of limestones and dolomites. The Devonian rocks are predominantly poorly productive shale, although they include water-yielding limestones along the Scioto River. The Silurian and Devonian rocks raised to the surface by the forces that created the Nashville Dome, do not cover a sufficient area to be of great significance in considering the regional ground-water situation.

Ordovician rocks of the Cincinnati Arch and Nashville Dome are separated by a "saddle" of younger rocks. In Kentucky, Mississippian rocks form the bedrock surface over most of the area between the two major structures. This area is drained by the streams of the upper Green River basin.

Areal Extent and Hydrologic Characteristics of the Bedrock Aquifers

Precambrian System.--Crystalline igneous and metamorphic rocks are sources of ground water only in a relatively small section of the Ohio Basin, where the New River drains a section of the Blue Ridge in North Carolina and Virginia. Ground-water supplies are obtainable from surficial portions of these rocks, which are fractured and weathered, and hence are moderately permeable.

Cambrian System.--Sedimentary rocks of Cambrian age form the bedrock surface only in a small portion of Virginia where the folded rocks of the Valley and Ridge Province are exposed along the edge of the Blue Ridge. The rock strata are composed of shales, siltstones, dolomites, and limestones, some of which are relatively impermeable in the areas where they form the bedrock surface and hence are not important sources of ground water, although some of the units are important sources of ground water.

Ordovician System.--Rocks of Ordovician age also are exposed along the folds of the Valley and Ridge, where they cover relatively small areas and are not considered hydrologically significant in terms of the overall hydrology of the eastern flank of the Ohio Basin. In the Virginia portion of the upper New River basin, limestones and dolomites are sources of moderate water supplies.

Ordovician rocks comprise the bedrock surface over two extensive areas in the west-central part of the basin as a result of uplift of the Cincinnati Arch and Nashville Dome. These structures underlie major portions of the Great Miami, Licking, Kentucky, and Cumberland River basins. The Ordovician rocks consist predominantly of interbedded limestones and shales. Shales are generally of low permeability and, where fractured, will yield only small supplies of water. In the Cumberland and Great Miami basins, the limestone interbeds are generally thin and yield little water.

Although the Ordovician rocks generally are sources of only small supplies in the Ohio Basin, one exception is in the Inner Blue Grass region near Lexington. Here, strata of middle Ordovician age are composed principally of thick, soluble limestones. Openings along fractures and bedding planes have been greatly enlarged due to the solution action of circulating ground water. Hence, where these solution openings are encountered by wells, large yields can be obtained. On the other hand, however, if the well misses the solution openings, it will yield little or no water.

Silurian System.--Silurian rocks form the bedrock surface around the peripheries of the Cincinnati Arch and Nashville Dome, and in narrow bands in the Valley and Ridge Province. The latter two areas are shown on plate 3 as Paleozoic rocks, undivided. With the exception of the broad area surrounding the Cincinnati Arch in Ohio and Indiana, the areas underlain by these rocks are not large enough to significantly affect the hydrology of the basin.

The Silurian rocks that form the bedrock surface in adjoining areas along the northern portions of the Scioto, Great Miami, and Wabash basins are composed principally of limestones and dolomites. These rocks are important aquifers in eastern Indiana and western Ohio. Water occurs in secondary openings along fractures and bedding planes that have been enlarged by the dissolving action of water. These openings are not of the cavernous types found in younger limestone formations around Mammoth Cave, Kentucky. The aquifer is permeable over a wide area, and many wells tapping these deposits in outcrop areas throughout the northeastern United States obtain adequate supplies of water for small industrial or municipal needs.

Devonian System.--Devonian rocks form the bedrock surface over three broad areas of the Ohio Basin. These areas include the New York section in the headwaters area of the Allegheny River basin, and adjoining parts of Pennsylvania; the center of the Scioto River basin above Columbus, Ohio; and the eastern and northern sections of the Wabash and White River basins of Indiana.

In the Allegheny basin, the Devonian rocks consist mainly of shales interbedded with fine-grained siltstones and sandstones and are not important sources of water. Only the Chemung Formation, composed predominantly of sandstones, is a good water producer, although wells tapping this formation were originally drilled for oil-production or test holes.

West of the Scioto River, the Columbus and Delaware Limestones of Devonian age and the Bass Island Group of Silurian age are important sources of water. The Upper Devonian rocks east of the Scioto River, on the other hand, are predominantly shale and are not significant sources of water supply. A similar situation prevails on the western flank of the Cincinnati Arch in Indiana, where the older Devonian limestones and dolomites yield 100 gpm or more of water to numerous wells, whereas the younger strata are mostly shales. Another band of Devonian rocks extending across the northern tip of the Wabash basin is also predominantly shale, and hence a poor source of water.

Mississippian System.--Mississippian rocks form the bedrock surface in widely separated bands throughout the Ohio River basin. Along the eastern edge of the Appalachian Plateau in Pennsylvania and West Virginia, the Pocono Formation, a sandstone unit, is capable of yielding moderate to large supplies of water, especially where it has been subjected to folding and is highly fractured. In the northwestern portion of the Allegheny basin, the Pocono is exposed along the beds of the Allegheny and Clarion Rivers and is a prolific water bearer.

Rocks of the Mississippian System extend southwestward across the northern part of the Beaver River basin and the northern and western parts of the Muskingum and Hocking River basins. In Ohio, they consist mainly of sandstones with some shales and are important water bearers. In southern Ohio and across the Licking and Kentucky basins, the Mississippian rocks grade into siltstones and shales that contain little ground water. A band of Mississippian limestones extends from the headwaters area of the Green River basin westward across the lower Cumberland basin and the southern tip of Illinois. Although these limestones are quite cavernous along the Green River in the Mammoth Caves area, and the source of many large springs, elsewhere they tend to be rather dense and will yield but small to moderate supplies of water to wells.

Another band of Mississippian rocks extending southward across the Wabash basin, Ohio River, and into the Green River basin, consists mainly of shales interbedded with siltstones, limestones, and sandstones. These rocks are generally rather poor sources of ground water.

Pennsylvanian System.--Rock strata of the Pennsylvanian System form the bedrock surface over about one-third of the area of the Ohio Basin, and most of the Appalachian Plateau. These rocks consist mainly of sandstone and the lower units are good sources of ground water over most of the eastern portion of the basin. The upper units tend to grade into siltstones and shales and are relatively poor sources of water in the areas where they form the bedrock surface.

Pennsylvanian rocks are sources of ground water in the lower Wabash basin in Indiana and Illinois. The basal units are deeply buried in the Little Wabash and Embarrass basins of southeastern Illinois, and in the lower part of the White River basin in Indiana. In these areas, the upper strata of the Pennsylvanian System yield little ground water.

The Pennsylvanian rocks are the principal coal-bearing formations within the Ohio Basin, and mining activities have significantly affected water quality in the coal-producing regions. The mines serve as collectors of ground water in the same manner as wells, and many of the abandoned

mines dug below the regional water table have become flooded. Some of these mines have been tapped for water supplies, although the drainage from these mines, especially in the eastern part of the Ohio Basin, has caused serious surface-water contamination because of the acidity imparted to the waters by various minerals present in the coal-bearing rock formations.

The Pennsylvanian sandstones are especially permeable along the western edge of the Allegheny Mountains where they have been folded in ridges and valleys. The relatively high permeability for the sandstone in this area no doubt is the result of fracturing of the strata and parting along bedding planes.

Despite the generalization of the geologic map showing the bedrock systems, and the various sub-drainage area maps showing sources of water in the bedrock formations, it must be emphasized that lithologic and hydrologic characteristics vary widely within and between the rock strata of the Pennsylvanian System. The maps therefore indicate broad areas where ground-water developments may or may not be favorable, but specific plans for development will require detailed study of the proposed project area. Within the Pennsylvanian rocks, it has been noted that conditions favorable for the development of ground water are more prevalent along the valleys than on the hilltops. Although the hydrologic-versus-terrain relationships are not definitely known, it is likely that the favorable conditions in the valleys result from increased secondary permeability due to the tensional forces resulting from the removal of great loads of sediment during downcutting of the valleys. Also, the streams are favorably situated for recharge of the underlying aquifers. Since the reverse situations prevail on the hilltops, this may explain the difficulties encountered in obtaining water supplies at hilltop locations.

Pennsylvanian and Permian Systems.--In southwestern Pennsylvania and adjacent parts of Ohio and West Virginia, the Dunkard Group forms the bedrock surface. The rocks, which are Pennsylvanian and Permian in age, are composed predominantly of shales and siltstones, and are poor sources of water, resulting in the reliance on surface sources for supply in the area.

Cretaceous and Tertiary Systems.--At the head of the Gulf Coastal Plain, Mississippian rocks are overlain by Cretaceous sands and gravels. These deposits are highly permeable and capable of yielding very large quantities of water. The Cretaceous sediments in some areas are overlain by water-bearing Tertiary sands. At the western end of the Ohio Basin, where these deposits are the thickest, individual wells are capable of producing as much as 800 gpm. Younger Tertiary sediments in the upland areas, however, are thin and yield quantities adequate only for domestic supply.

Potential for Development of Ground Water from the Bedrock Aquifers

Many of the surficial bedrock formations of the Ohio River basin comprise important aquifers, and, with the exception of the map showing sources of ground water in the Cumberland River basin, maps for all the sub-drainage areas indicate the presence of bedrock aquifers capable of yielding 100 gpm or more to individual wells. Broad portions in all of the sub-drainage areas are underlain also by bedrock aquifers capable of yielding 20 to 100 gpm to individual wells.

Whereas in terms of quantity, 20 gpm is negligible compared to the amount of water that can be withdrawn from a stream or reservoir, it must be remembered that 20 gpm equals more than 25,000 gpd, or enough to supply 100 gpd per capita for 250 people. It then becomes apparent that the widespread occurrence of relatively small sources of water makes this resource very valuable, because ample water supplies commonly may be developed at or near the point of need instead of importing it from the nearest stream. As stated above, however, the designation of an area as one of "greatest potential for development" does not mean that any well drilled at any point in the area will yield at least the quantity of water indicated. The maps should be interpreted to mean that the probability of obtaining supplies in the amounts indicated for the areas of greatest or intermediate potential is far greater than in the area shown as having the least potential.

The development of ground water from bedrock aquifers, however, should not be considered without examining the physical relation of the aquifer with the streams in the area. Development of aquifers near streams has the advantage of a nearby source of induced recharge to the aquifer. The use of ground water that has been recharged by a nearby stream commonly eliminates problems associated with bacteria, turbidity, and temperature extremes.

The areas of greatest potential for development of bedrock sources for ground-water supply are those underlain by Mississippian and Pennsylvanian sandstones in the Allegheny, Beaver, Muskingum, Monongahela, Kanawha, Guyandotte, and Big Sandy River basins; and those underlain by Silurian and Devonian limestones in the Scioto, upper Great Miami, and Wabash basins. The areas of least potential are those underlain by interbedded limestones and shales of Ordovician, Silurian, and Devonian age in the Kentucky and Cumberland River basins, and Permian rocks along the Ohio River above Point Pleasant.

Geology and Hydrology of the Unconsolidated Sediments

The great potential for ground-water development in the Ohio River basin results largely from the presence of very widespread and permeable sand and gravel deposits. Approximately the northern third of the basin is covered by drift deposited by a succession of continental glaciers (pl. 4). The streams draining the glacial deposits have redeposited the glacial and other sediments in the valleys within and beyond the line of furthest encroachment of the glacial ice, and in the Ohio River valley itself. Alluvial deposits not directly associated with glacial processes also partly fill the lower reaches of the major streams entering the Ohio River from the south.

Types of Unconsolidated Sediments and Their Water-Bearing Characteristics

The principal types of glacial sediments present in the Ohio Basin are till, outwash, and glacial-lake deposits:

Till.--A heterogeneous mixture of clay, silt, sand, and gravel, which has a very low permeability and is therefore a poor source of water. Within the areas underlain by till-plain and morainal deposits (pl. 4), washed deposits of sand and gravel occur as lenses or pockets interbedded in the till, which may yield as much as 20 gpm to wells.

Outwash.--Composed predominantly of sand and gravel washed by meltwater streams, and generally very permeable and an excellent source of water. The outwash deposits are most prevalent in the valleys of major streams within and beyond the limits of glaciation. Where these deposits fill the valleys beyond the limit of glaciation, they are referred to as valley-train deposits. Along the present streams, they are intermixed also with Recent sediments deposited by the stream and hence are technically known as glaciofluvial (glacial and alluvial) deposits. The valley-fill outwash deposits have the greatest potential for development of any ground-water source in the basin.

Glacial-lake deposits.--Predominantly fine silt and clay deposited in lakes impounded by advancing ice during the glacial epoch. These deposits are of low permeability and are poor sources of water. Within the Ohio Basin, however, they form the surficial deposits only in limited areas and hence are not shown on plate 4.

Recent river alluvium consisting of silt, sand, and gravel is present in the lower reaches of the major stream valleys south of the Ohio River. These sediments are generally finer grained and less permeable than the glaciofluvial deposits in the Ohio River valley, and the major tributaries north of the Ohio River. They are potentially important, however, in that the streams flowing over them are a potential source of recharge that may compensate for the smaller permeabilities of these sediments.

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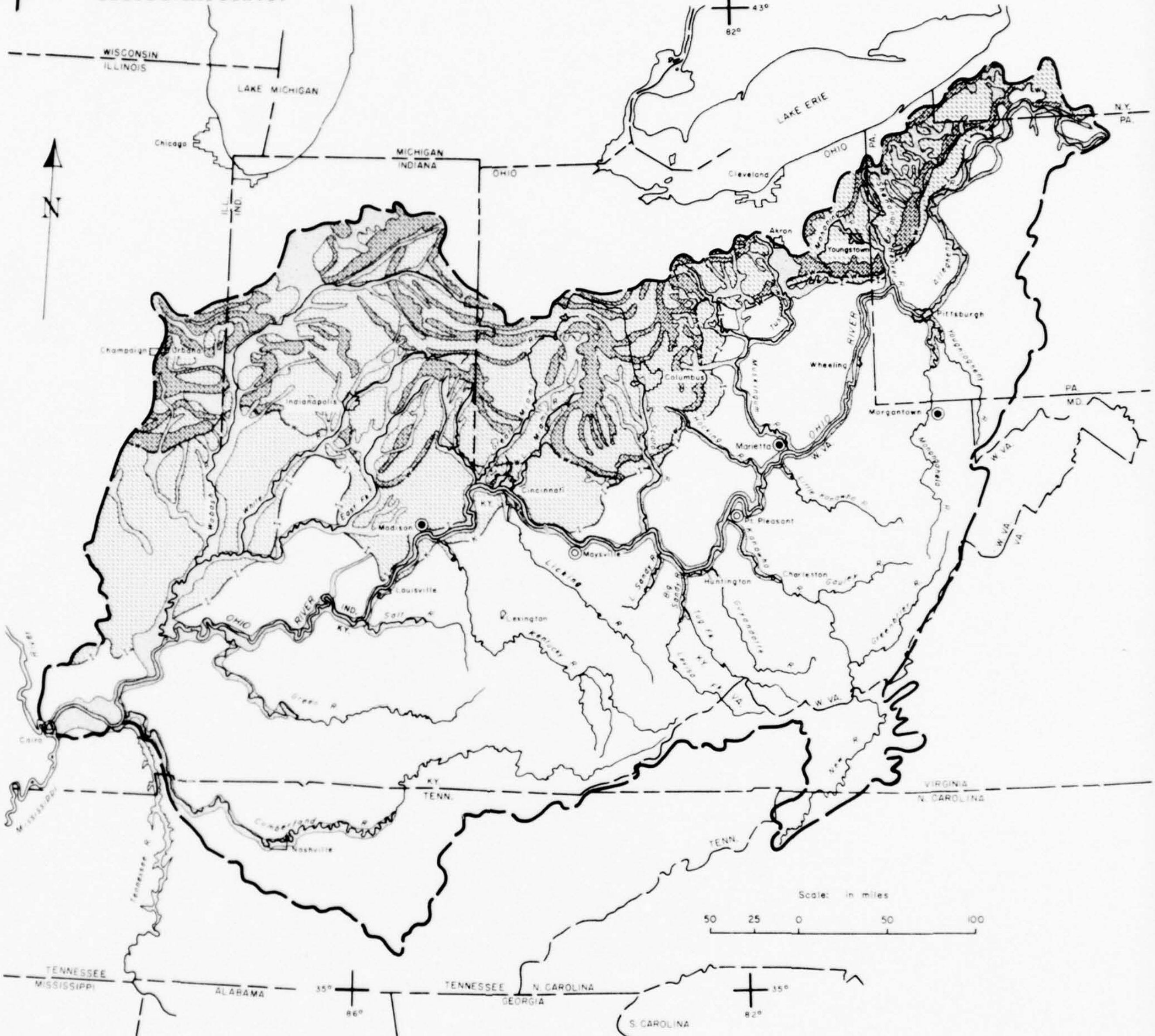


EXPLANATION

TILL

Till plain deposits: poorly sorted clay, silt, sand, and gravel underlying till plains. Includes glacial-lake clay and silt, and pockets of sorted sand and gravel, especially within areas of Wisconsin glaciation.

Morainal deposits: unsorted till deposits with incorporated sand and gravel outwash, forming low ridges along former fronts of glacial ice sheets.

OUTWASH

Sorted sand and gravel deposits within the glaciated area and in valleys of streams draining these areas.

ALLUVIUM

Clay, silt, sand, and gravel deposits along major streams draining unglaciated areas.

SOUTHERN LIMITS OF CONTINENTAL GLACIATION

W——W Wisconsin Glaciers

I——I Illinoian Glaciers

K——K Kansan Glaciers

POPULATION
(1960 Census)

more than 25,000

10,000-25,000

5,000-10,000

Adapted from:

Geological Society of America, 1959, Glacial map of the United States east of the Rocky Mountains.

Goldthwaite, R. P., White, G. W., and Forsythe, J. L., 1961, Glacial map of Ohio: U.S. Geol. Survey Misc. Geol. Inv. Map I-316.

Shepps, V. C., White, G. W., Droste, J. B., and Sitler, R. F., 1959, Glacial geology of northwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. G-32.

Wayne, W. J., 1958, Glacial geology of Indiana: Indiana Geol. Survey, Atlas of Mineral Resources of Indiana, Map No. 10.

OHIO RIVER BASIN DISTRIBUTION OF UNCONSOLIDATED SEDIMENTS

PLATE 4

Regional Distribution of the Unconsolidated Sediments

The valley-fill sediments, consisting both of glacial outwash and Recent alluvium, in the valley of the Ohio River from Pittsburgh to its confluence with the Mississippi River, is the most important single source of ground water in the Ohio River basin. The scope of this preliminary study was inadequate to attempt to estimate the volume or the geometry of the permeable sediments within the valley fill along the Ohio; however, considering the length, which is almost 1,000 miles, the width of the valley, ranging from about ½ to 10 miles, and the saturated thickness of the permeable zones, ranging from about 20 to 100 feet, the volume of water within the aquifer is enormous.

The valleys of the following rivers, as well as those of many of their major tributaries, are filled with permeable glaciofluvial sediments capable of yielding very large quantities of water either naturally or under conditions of artificial recharge: the Allegheny, Muskingum, Hocking, Scioto, Little Miami, Great Miami, Whitewater, White, and Wabash.

There is no basis for closely estimating the areal extent and thicknesses of the outwash in the minor stream valleys, and the washed deposits within the till plain areas, but throughout large portions of the glaciated areas supplies adequate for smaller municipal or industrial demands are available. Areas described on the maps showing sources of ground water in the unconsolidated sediments as having least potential for development are greatly generalized, and detailed investigations or test drilling may reveal the presence of permeable drift capable of yielding larger quantities than those shown. This is especially true in the areas covered by thick glacial deposits of Wisconsin age.

Alluvial deposits in the valleys of the major streams flowing to the Ohio from the south also comprise important aquifers. These deposits are present in the lower reaches of the Monongahela, Little Kanawha, Kanawha, Guyandotte, Big Sandy, Little Sandy, Licking, Kentucky, Salt, Green, and Cumberland River valleys. Little study has been made on the water-yielding capabilities of these deposits, however, and their potential for future development is not known. However, the comprehensive study being made by the U.S. Geological Survey for the Kanawha River basin will provide additional information on the hydrologic characteristics of the alluvium in that valley below Charleston.

Development Potential of the Unconsolidated Sediments

If the demands for ground water in the Ohio River basin greatly increase as presently predicted, the valley-fill aquifers will provide the major source of additional supplies because of five important factors:

1. Their capabilities of providing large quantities of water at rather localized points of development.

2. The major streams flowing over them provide perennial and bountiful sources of recharge.

3. Most of the larger urban and industrial centers of the basin are conveniently situated to tap these aquifers.

4. The water obtained from these aquifers will generally be lower in bacteria and turbidity, and have more constant temperatures than water in nearby surface streams.

5. The water from the valley-fill aquifers tends to be lower in dissolved mineral content than that from the bedrock aquifers.

Most of the large urban centers are located along the permeable glaciofluvial valley-fill deposits in and north of the valley of the Ohio River; for example, Wheeling, Huntington, Cincinnati, Louisville, Evansville, and Paducah on the Ohio River, and Pittsburgh, Zanesville, Columbus, Dayton, Indianapolis, and Terre Haute on major northside tributaries. Notable exceptions are Akron, which is located on the Ohio-Great Lakes basin divide, and Youngstown along the relatively small Mahoning River.

In the southern part of the basin, excepting those cities on the Ohio River, only Charleston is favorably situated to tap valley-fill deposits. Most of the other major cities are along rivers that can be tapped directly for water. A notable exception is Lexington, which is situated in a divide area between relatively small tributaries of the Kentucky River.

Throughout the glaciated area, pre-glacial drainage patterns were blocked and their valleys filled with glacial debris. (The locations of some of the major drainage courses are plotted on the maps showing sources of ground water in the unconsolidated sediments.) Although much local interest has been given to the water-yielding potential of the sediments in the buried valleys that are not now occupied by perennial streams, they

cannot rival the valley-fill deposits along the present major streams for several reasons: In many places they are filled with till, rather than outwash deposits; except where they coincide with the courses of present major rivers, such as the lower Scioto, they do not have large streams available for recharge; the demands for water will be greatest in the urban and industrial areas, which are located on present--not abandoned--watercourses.

Effects of Geology on Streamflow Characteristics

The dry-weather flow of streams in the Ohio River basin, as well as in other humid areas, represents to a great extent the discharge of ground water. The relationship between the low-flow characteristics of a stream and the geologic conditions in its drainage area provide an indication of the hydraulic characteristics of the aquifers of the basin. For instance, if the low-flow index (as used herein, the 90 percent duration flow or the flow equaled or exceeded 90 percent of the time, in cfs per square mile) is relatively high for the basin, it indicates that the stream receives a relatively large percentage of its flow during dry weather from ground-water discharge. On the other hand, a low dry-weather flow index is characteristic of a "flashy" stream, which receives most of its flow from overland runoff following precipitation and receives relatively little increment to flow from the discharge of ground water. This, of course, applies to streams flowing under natural conditions, and not to streams whose flow is subjected to regulation or diversion.

The streams draining the glaciated portions of the Ohio Basin have a higher sustained flow than those draining unglaciated areas. Further, those draining permeable bedrock formations are higher than those draining bedrock formations of low permeability. For example, in the Great Miami River basin, the West Fork Whitewater River near Connersville has an index of .14 cfs per square mile, which is fairly typical for streams whose drainage areas are underlain by permeable outwash deposits. On the other hand, Whiteoak Creek, which drains an unglaciated area east of the Little Miami River basin in Ohio, has a low-flow index of only .012 cfs per square mile (see pl. 5).

In the Monongahela River basin, Dunkard Creek, above its confluence with the Monongahela River, has a low-flow index of .02, whereas the Blackwater River at Davis has an index ten times higher at .21. The flow of Dunkard Creek is mainly over shales of the Dunkard Group, whereas the Blackwater River drains portions of the Greenbrier Limestone and permeable sandstones of the Pottsville and Allegheny Formations. The difference in the low-flow indices between these two streams clearly indicates the difference in the potential for ground-water development between the drainage basins of the two streams.

The differences in the hydrologic characteristics within the same rock formation can also be inferred from the low-flow indices. The upper Licking River in Magoffin County, Kentucky, which drains sandstone strata of Pennsylvanian age, has an index of .014, whereas the upper Guyandotte

River in Logan County, West Virginia, draining the same rock units, has an index of .068. These data indicate that the Pennsylvanian sandstones in the upper Guyandotte basin are more permeable, or have a greater aggregate thickness of permeable zones, or both, than do the same units in the upper Licking River basin.

Comparisons between the streams draining to the Ohio River from the north versus those draining from the south are afforded by the indices of the major tributaries (pl. 5) as computed from data collected at the gaging station nearest their mouths. The highest index (.29) is for the Beaver River, reflecting the relatively great extent of low-flow augmentation by the numerous reservoirs in the upper basin. The next highest is for the Kanawha River at Charleston (.26) reflecting the heavy precipitation belt in the headwaters area, regulation, and favorable ground-water conditions, or all three. The index of .19 for the Monongahela River probably reflects similar conditions for that basin. The index of .15 for the Cumberland River reflects the extensive regulation by power dams and navigation structures in the Cumberland basin.

In general, low-flow indices for the northern tributaries are greater than those of the southern basins. In the northern basins only the Scioto River has an index less than .10 (.086), in contrast to the southern basins where the Big Sandy, Licking, Kentucky, and Green Rivers have indices less than .10. These data are indicative of high ground-water yields from the outwash deposits along the northern streams of the Ohio River basin.

GENERAL GROUND-WATER QUALITY CHARACTERISTICS

The quality characteristics of ground water, as well as those of surface water recharged to the ground, must be considered in the comprehensive planning for development of the water resources of the Ohio Basin. Quality factors that will favor the development of ground water are its general lack of bacterial pollution, low turbidity, and relatively constant temperature and relatively constant mineral content. The chief quality factor favoring the development of surface water is its generally lower mineral content. Quantity considerations and the feasibility of multi-benefit developments, however, often favor surface-water developments.

In the eastern portions of the Ohio Basin, from the Allegheny basin to the Blue Ridge in North Carolina, ground water at shallow depths in the surficial aquifers is generally soft and relatively low in mineral content. This is especially true for the widespread Pennsylvanian sandstone aquifers in Pennsylvania and West Virginia. Excessive iron concentrations, however, are common in these waters. With increasing depth, sodium chloride concentrations tend to become excessive, although the depths at which the water becomes too saline for most uses varies widely. Very detailed studies would be needed to map the altitudes and configuration of the fresh-saline water interface, but the results to be obtained from a basinwide study of this nature would not merit the time and cost involved, although such studies would be economically feasible and actually needed as a basis for planning specific developments.

Problems of excessive chloride concentrations have been encountered in several petroleum-producing regions within the Ohio Basin. In the Allegheny, Scioto, Wabash, and Green River basins, brines encountered in permeable formations during the course of oil-production or test well drilling have entered streams and may have affected fresh-water or streamside aquifers in these oil-producing areas. Further studies delineating the brine-contamination problem are being carried out by the Public Health Service.

The rocks of the Pennsylvanian System are the sources of coal that is mined over broad areas of the Ohio Basin. The discharge of acid waters from mines to nearby streams has been of great concern for a least three decades, and there appears to be no ready or economically feasible solution to this problem. The tapping of ground-water sources appears to offer a partial alternate solution for water supplies. Ground water that has not flowed through mines in the presence of oxygen tends to be free from acid. On the other hand, minerals in the coal-bearing formations impart acidity to water flowing through mines and other open channels, apparently as a result of the presence of oxygen.

It has been noted that wells tapping the alluvium and industrial slag along the lower Monongahela River produce water of neutral quality, although the river water tends to be acid. It is not known whether the source of the well water was from aquifers upgradient to the stream, or from induced recharge from the stream itself. An investigation of the hydraulic and quality relationships is urgently needed, because if it were found that the latter condition existed, induced recharging of acid stream waters to streamside aquifers of certain mineralogical types may offer an efficient means of neutralizing or buffering acid mine waters.

In areas where limestones and dolomites comprise important aquifers, problems associated with excessive mineral concentrations and hardness are generally encountered. In Ohio, Indiana, and Kentucky, where limestone and dolomite formations are important sources of water supply, softening is an essential treatment. Sulfur-bearing minerals, especially gypsum, are the source of calcium sulfate, with its associated hardness problems; especially in east-central Indiana and west-central Ohio where limestone and dolomite aquifers of Silurian age are prolific sources of ground water. In some localities, hydrogen sulfide in water produced from these aquifers is a source of taste and odor problems.

The removal of iron is needed inasmuch as iron concentrations in most ground waters of the basin are excessive. This is the case in the hard-water as well as soft-water areas.

Where limestone aquifers are highly permeable because of the presence of caverns and open channels, the aquifers are highly susceptible to contamination from surface sources. In this respect, the contamination occurs in the same manner as surface-water contamination. The contaminant enters the water without the benefit of the natural treatment processes afforded by the percolation of water through porous media, such as oxidation in the zone of aeration, filtration, ion exchange, sorption, or various biochemical processes. The limestone aquifers of the Greenbrier, Kentucky, and Green River basins are especially susceptible to contamination such as has been reported in the Lexington area.

The quality of ground water in the glacial drift and alluvial aquifers generally reflects the source of these sedimentary deposits. The water in the glacial-drift aquifers of the northern drainage basins is generally very hard and high in mineral content, especially calcium, magnesium, bicarbonate, and sulfate. This is explained by the fact that much of the drift was derived from the limestone, dolomite, and shale bedrock common along the northern portions of the Ohio Basin, as well as from source areas farther to the north.

A common misconception is that water from glacial-drift aquifers is of better mineral quality than water from the underlying bedrock. This is not necessarily true. It must be remembered that ground water derives its principal mineral characteristics from the media through which it has moved, and that percolation need not have been limited only to the aquifer from which it is pumped by the well. Thus, where a glacial-drift aquifer is being recharged by a stream or directly from precipitation, the quality of water in it may be superior to that in the underlying bedrock. Where ground water is discharging to a stream from a bedrock formation through the overlying glacial drift, the quality of water obtained from the drift will be essentially the same as that from the underlying bedrock aquifer.

Quality considerations will tend to favor the conjunctive development and use of ground water and surface water. As indicated repeatedly throughout various parts of this report, increased water demands likely can be met by recharge facilities tapping the major valley-fill aquifers. Inducing the flow of surface water into these aquifers will have some beneficial, but possibly also some detrimental effects: Pathogenic bacteria are generally removed, the water is naturally filtered, temperature variations are reduced, and some contaminants may be removed or degraded. On the other hand, once some contaminants such as phenolic compounds, chromates, detergents, chlorides, and other stable minerals enter the aquifer, the contamination may persist for prolonged periods of time. Therefore, no recharging operation should be planned without prior study of the probable effects of the recharge on ground-water quality. Such a study should be coordinated with the State agency that has authority to approve such a recharge operation.

The valley-fill deposits along the Ohio River have already been described as the most important aquifer of the Ohio River basin. The Ohio River, therefore, will provide the most important source of recharge. The quality of the water pumped by wells tapping the valley-fill deposits reflects the source of the water. Under normal conditions, the ground water in the valley fill has a chemical composition similar to the waters in adjacent bedrock formations, except when the river stage is high and the aquifer is being recharged by the river. Under induced recharge conditions, the surface water elevation is always higher than the ground-water table. Because the Ohio River is the receiving stream for a great variety of wastes, recharging operations could well endanger the valley-fill aquifer. The future beneficial development of the Ohio River valley-fill aquifer will depend to a large extent on the success of pollution-abatement and quality-control programs throughout the entire Ohio River basin.

The construction of dams should generally have beneficial effects on ground-water quality, especially where the fresh-saline water interface is high enough to be of concern. The raising of ground-water levels due to the increase in stage of the river will not only increase the volume of ground water in storage, but also increase the thickness of the fresh-water zone and at the same time tend to depress the interface. This in turn increases allowable drawdowns due to pumping before encroachment of saline water to the well occurs.

Typical ranges in concentration of key mineral constituents in ground water are included in tables in each of the sub-drainage area reports. These concentrations were taken from published data for indications of the general quality types of ground water. Concentrations are reported in milligrams per liter (mg/l) in accord with the preferred usage of the Public Health Service. The chemical data provided is not adequate for the comprehensive planning for development of the ground-water resources of the Ohio River basin; however, further water-quality studies are being made by the Public Health Service and Geological Survey.

USE AND MANAGEMENT OF GROUND-WATER RESOURCES

Traditionally, ground-water supplies have been developed primarily for use at points of need. Hence, because many of the aquifers of the Ohio River basin cover hundreds and even thousands of square miles, cones of depression resulting from large-scale pumping amount to relatively small areal development in these extensive aquifers. Most of the aquifer, therefore, is left untouched and the water stored in it, unused. The piping or transferring of ground water for considerable distances from areas of availability to points of need is rare in the Ohio Basin. A notable exception to the traditional pattern of development is offered by Canton, Ohio, which taps a valley-fill deposit and pipes the water about 17 miles upbasin for use in the city.

Many of the larger cities in the northern part of the basin obtain their water supplies from streams and reservoirs. Where conditions are favorable for ground-water development in such areas, some important benefits can be derived from this resource. The water stored in aquifers in areas served by surface sources can be used to supplement existing supplies, or for alternate supplies in the event of emergency. For example, during the drought of 1963 in central Ohio, there was great concern about diminishing supplies in the surface reservoirs in the area. None of the cities relying upon ground-water sources for supply reported shortages. At Columbus, the city placed a well field into operation to supplement its existing surface-water supply. Ground water, with its relatively constant temperature, might also be used to cool surface water in the summer, warm it in the winter, and reduce the fluctuations in mineral content, as is done by Findlay, Ohio, in the Lake Erie basin.

Possible New Ground-Water Applications

Because the ground-water resource is plentiful as well as widespread, there appears to be little doubt that this resource could be put to beneficial uses other than that of supplying needs at points of demand, or of limited quality-control applications. The solution of some of the serious water problems in the Chio Basin could lie--at least in part--in several new applications of the ground-water resource. Some suggested uses are as follows:

Pumpage of ground water to augment the dry-weather flow of streams. (Newark, Ohio, employs this technique to increase the flow and improve the quality of the Licking River above the city's intake.)

Pumpage of ground water for surface reservoir replenishment during dry-weather periods. Lowered water levels reduce the value of reservoirs for recreational and water supply uses at a time when the demand is greatest, whereas the lowering of ground-water levels does not have the same detrimental effects.

Use of ground water where available to replace surface-water sources tapped for irrigation. The diversion of surface water for irrigation generally coincides with the periods of lowest streamflow, thus tending to aggravate problems associated with low-flow conditions. By pumping ground water from storage at points remote from the streams, demands on the stream will be curtailed during low-flow periods.

The desire for multi-benefit applications favors the development of surface water rather than ground water where water from both sources is available. The anticipated increased demands of the future will no doubt result in increased conjunctive use of surface and ground water for specific needs. This use may be of the types listed above, in which ground water will be pumped to augment surface-water supplies. When the situation is reversed, however, and surface water is used to recharge or refill aquifers, surface-storage facilities such as recharge ponds or channels will become common. The planning of such facilities should also take into consideration possibilities for multi-benefit applications. At Kalamazoo, Michigan, recharge ponds--in addition to their chief hydrologic function of replenishing aquifers--were also designed for beautification in urban renewal projects; a focal point for new municipal parks where they are used for swimming, boating, fishing, or merely for aesthetic enjoyment; and for general economic improvements in the project areas.

The scope of the present investigation was inadequate to explore possibilities for multi-benefit projects employing the concepts of conjunctive use of waters; therefore, the following is offered merely as an example for planning purposes by action agencies:

Consider the hydrologic situation of the Cincinnati area. The Great Miami River drains one of the most prolific ground-water areas of the Ohio River basin. The river flows by the western limits of Cincinnati and the Whitewater River flows into the Great Miami a few miles above its mouth downstream from the city. The Little Miami River flows through the eastern part of the city. Despite the great water supply potential of these major streams, much of the huge industrial complex of Cincinnati is situated along Mill Creek. This small creek flows in part along an old course of the Ohio River. The pumping for industrial water supplies from the glacial deposits underlying Mill Creek has caused serious dewatering of this aquifer. Most of the water in the basins of the major rivers in the Cincinnati area flows unused into the Ohio River.

There are a number of hydrologically feasible solutions to the water-supply problems of Cincinnati, some of which could have great supplemental benefits. These include the construction of recharge facilities in the Mill Creek valley, using water imported from any of the three major rivers in the area, or perhaps all three. The aquifer underlying Mill Creek has a large available storage capacity. If transfer of water from the major river basins to Mill Creek could be effected by canal rather than pipeline, the connecting waterways perhaps could be used by small craft for recreational purposes. Enlarging and deepening of Mill Creek by dredging or the construction of low-head dams could make the streamside area desirable for parks or perhaps a park system similar to the Huron-Clinton Metropolitan Park system ringing Detroit. In the same manner, off-channel recharge ponds could provide the nucleus for small parks in the valley. The dredging of the channel might result in increased infiltration to the underlying aquifer. In the Mill Creek valley, owing to the presence of a thick layer of clay and silt overlying the aquifer, other recharging techniques might have to be employed. These could include direct injection of water to the outwash deposits through wells, or perforation of the clay and silt deposits by large diameter augers.

Comprehensive river basin development will be greatly aided by imaginative planning as to how water-resource developments, especially those of a pioneer nature, might be extended to include benefits other than increased water supplies. Whenever the raising of river stage, or the cleaning or dredging of a stream channel is planned for artificial recharge purposes, extension of such construction for added recreational or beautification benefits should be considered.

Problems in Regional Ground-Water Development

Probably the greatest obstacle to comprehensive development of the water resources of the Ohio Basin will be to arouse public awareness that ground water is a prolific resource that can be developed regionally, rather than solely at points of need. Also, the general public misconception that "ground-water levels are falling all over the country" must be dispelled. In the Ohio Basin, water problems that the public construes as those related to water shortages are for the most part really problems related to water quality or inadequate facilities. Knowledge concerning the hydrologic functioning of the basin and the quantity-quality relations that exist is a requisite for sound water development and management techniques that will gain the maximum benefits from the water resources of the basin. The technical problems involved in conjunctive water developments are more fully discussed in the various sub-drainage area reports, and in the preceding discussion on ground-water quality characteristics.

An important advantage of ground-water use is that it is commonly possible to develop water supplies at points of need. The natural storage capacity of an aquifer, of course, eliminates the need for land acquisition and dam construction as required for surface reservoirs. On the other hand, ground water generally requires test drilling, a variety of treatment, and associated waste-disposal techniques, and maintenance, cleaning, and refurbishing of pumps and well screens. The planning of individual facilities where both ground-water and surface-water sources appear adequate for estimated needs will require that costs and benefits be considered for all alternate development possibilities, including the use of one source or the other, or various combinations thereof.

Administrative and legal problems will also be encountered in comprehensive water development planning. Throughout this report, the advantages of conjunctive water developments are stressed. Put into its simplest terms, however, the surface streams of the basin may be classified as interstate, and thus to some degree are under federal control. Ground-water resources, on the other hand, are traditionally under the jurisdiction of the states. It can be seen, therefore, that conjunctive use projects will require very close federal-state cooperation. The possible hydrologic inappropriateness of existing law covering the waters of the Ohio Basin, possible legal impediments to gaining optimum benefits from the resource, and whether or not new legislation is desirable, all need to be intensively studied.

Sound planning and management may call for interbasin transfers of water, which is contrary to the accepted concept of the riparian doctrine as practiced in the eastern states. Strict adherence to this doctrine could prevent developments of the type suggested above for the Cincinnati area. Also, it is not clear as to how such projects would be affected by statutes of the various states, such as the Conservancy Act of Ohio.

Sixty percent of the Appalachian Region falls within the Ohio River basin, and water developments will certainly result from actions of governmental and private agencies in furthering the economic recovery of that region. Further, that portion of the Ohio River basin west of the Appalachian Region is presently experiencing rapid increases in population and industrial expansion. Thus, because of its widespread availability and potential for increased beneficial use, ground water will play an increasingly important role in the economic growth of the entire basin.

GENERAL CONCLUSIONS

The ground-water resources of the Ohio River basin provide great potential for future development. It is apparent, however, that this potential will be limited by water-quality problems, relating to the natural quality of the ground water as well as to contamination of both ground and surface waters. The glacial and alluvial sediments, filling the valley of the entire course of the Ohio River from Pittsburgh to Cairo, have a tremendous capacity for future development. Although many municipal and industrial water supplies are obtained from the valley-fill deposits along the Ohio River, these developments are insignificant when compared with the total water-yielding capability of the aquifer. The volume of permeable sediments is obviously enormous, and the Ohio River itself provides an extremely large source of water to recharge the underlying valley fill. Development will be limited by the technical problems of recharging these sediments and by the quality of the water of the Ohio River itself, as well as by economic considerations.

The valleys of the major tributaries discharging to the Ohio River from the north are filled with permeable glacial outwash deposits. Development patterns in these prolific aquifers are similar to those of the Ohio River valley-fill deposits in that their potential has been utilized only at a few metropolitan centers. The technical problems that will be encountered in the development of these aquifers are the same as those of the Ohio River valley fill; namely, those of recharging the sediments with surface water and of protecting the aquifers from pollution.

Ground-water development will not be limited, however, to areas north of the Ohio River, as bedrock aquifers are rather widespread in many areas of the basin. Sandstone formations of Mississippian and Pennsylvanian age, for instance, will provide water supplies for future needs over large areas throughout most of the states of the basin. Similarly, Silurian and Mississippian limestone and dolomite deposits can provide for future needs over large areas of Ohio, Indiana, and Kentucky. Only in relatively small areas of the Ohio Basin are ground-water conditions so unfavorable that it is difficult to obtain even small supplies of water for domestic needs. One such area covers adjoining parts of Pennsylvania, Ohio, and West Virginia where shales of the Dunkard Group comprise the bedrock surface.

It is apparent that greatly increased demands for water in the Ohio Basin will require that quality considerations be studied in greater detail. The needed quality studies pertaining to ground-water development cannot be restricted to ground water alone, but must include the effects on quality caused by interflow of water between surface and subsurface sources.

SUB-DRAINAGE AREA REPORTS

The following sub-area reports propose a number of items that future water managers might consider in attempting to provide for comprehensive and beneficial developments. Further, these reports cite the need for studies of various types. Management of the basin's ground-water resources, in order to result in optimum benefits to users in the future, must be based on knowledge concerning the distribution and potential for development as described herein, as well as knowledge of the functioning of the hydrologic system.

Extent of Detail

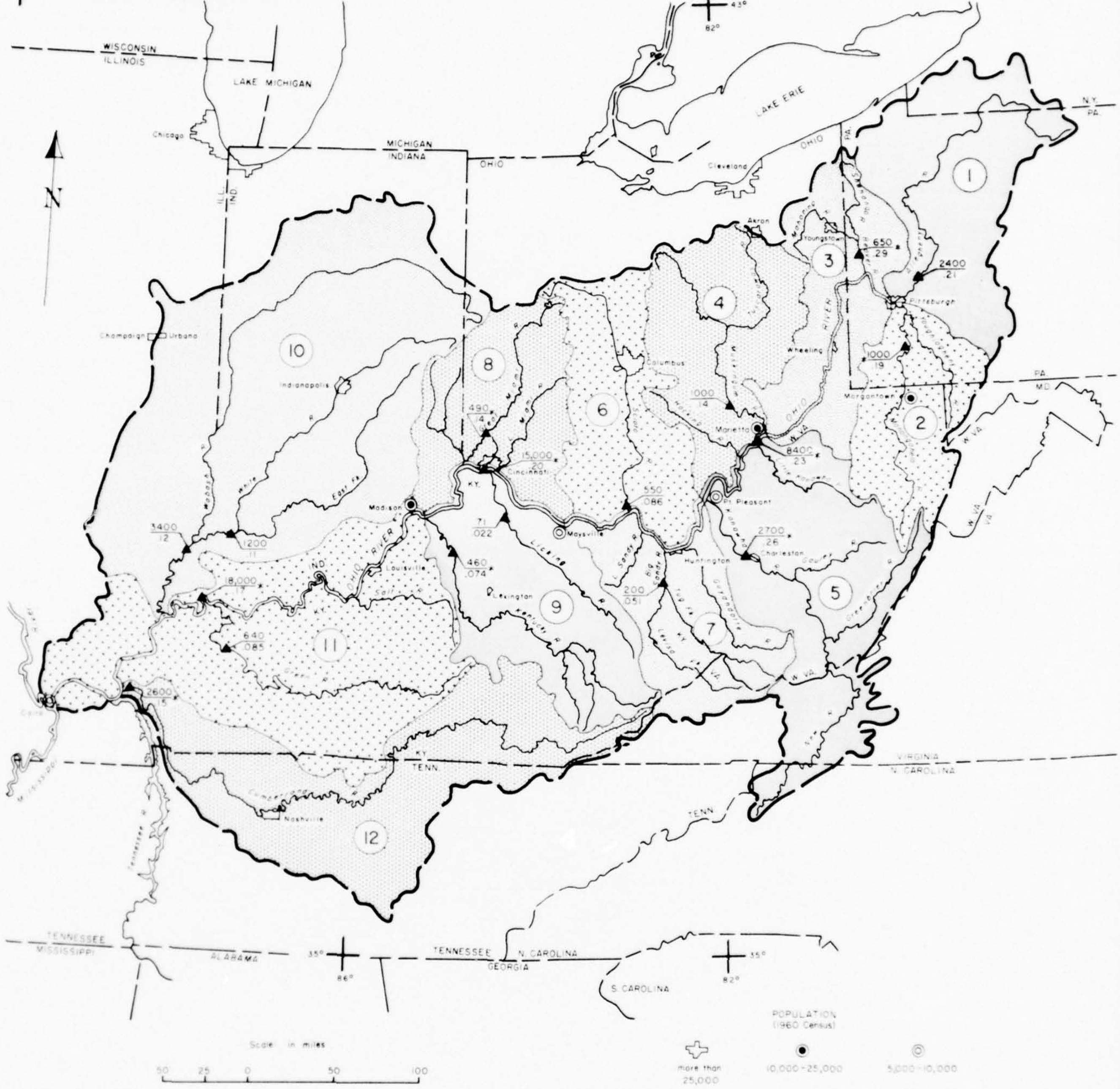
For the purposes of this report, the Ohio River basin was divided into 12 geographic areas, based mainly on the drainage boundaries of the principal tributary streams (pl. 5). During the course of the investigation interim reports were prepared for each of these areas. These reports list the principal aquifers, describe their hydrologic characteristics, the general uses of the water from the various aquifers, outline the status of available ground-water information, and discuss factors deemed significant in the future development and management of the area's ground-water resources.

A table in each report lists typical maximum yields and depths of wells tapping the chief aquifers. The well yields are based on available information for municipal and industrial wells, which are more indicative of the volumes of water an aquifer is capable of yielding to wells than data from domestic wells that commonly reflect only the limited needs of the user. The yields listed, therefore, must not be construed as a quantitative index of the water-yielding capability of an aquifer, but merely as an indication of the magnitude of the yields presently obtained from these aquifers.

Each table also provides information concerning the basic natural chemical quality of water from the chief aquifers in each sub-drainage report area. Characteristic ranges of hardness, sulfate, chloride, iron, and dissolved solids content are given as taken from published information. Because the full development of the basin's water resources is more likely to encounter problems of quality rather than quantity, provision has been made by the Public Health Service for the U.S. Geological Survey to broaden the scope of the quantity and quality coverage in a separate, but coordinated, project during the 1965-68 fiscal year periods of the comprehensive study of the Ohio River basin.

The ground-water problems presently faced and anticipated, possibilities for development, possible solutions of problems, or research needs are listed in the sections entitled "Management Considerations". These sections can provide a basis for future studies or alternative management plans.

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



SUB-DRAINAGE AREAS DESCRIBED IN THIS REPORT

1. Allegheny Basin
2. Monongahela Basin
3. Upper Ohio River drainage area
4. Muskingum and Hocking Basins[1]
5. Kanawha and Little Kanawha River Basins[1,3]
6. Scioto Basin[1]
7. Guyandotte, Big Sandy, and Little Sandy Basins[1,3]
8. Great Miami and Little Miami Basins[1]
9. Licking and Kentucky Basins[1,3]
10. Wabash Basin
11. Lower Ohio River drainage area[2]
12. Cumberland Basin

[1] Includes adjacent small tributary basins draining directly to the Ohio River

[2] Exclusive of the Wabash and Cumberland Basins

[3] Includes Ohio River alluvium

Stream gaging station

2700 — Flow equalled or exceeded 90 percent of the time, in cfs
26 — Flow equalled or exceeded 90 percent of the time, in cfs per sq. mi.

Note: Flows indicated (*) are affected by regulation or diversion

DRAINAGE AREAS
OF THE
OHIO RIVER BASIN
DESCRIBED IN THIS APPENDIX

PLATE 5

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 1

ALLEGHENY RIVER BASIN

By

Morris Deutsch and Joe C. Wallace

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISICN
Mid-Continent Area

ALLEGHENY RIVER BASIN

CONCLUSIONS

Abundant supplies of ground water are available for future development within the Allegheny basin. The greatest potential lies in the area north of the Clarion River, especially within the glaciated area, and along the entire course of the Allegheny River. South of the Clarion River, small to moderate supplies of good-quality ground water are available from numerous sandstone strata. In the headwaters area of the Conemaugh River, large ground-water supplies have been developed.

The principal aquifers of the basin, and sources for possible future development in estimated decreasing order of potential, are as follows:

1. Outwash deposits, especially in the valleys of streams tributary to the Allegheny River within the area covered by Wisconsin Glaciation.

2. Glacial and alluvial sediments along the entire course of the Allegheny River from its source to Pittsburgh, and in the valleys of tributary streams to the Allegheny above Tionesta draining the unglaciated area.

3. Sandstone units of the Pocono Formation where it forms the bedrock surface in the northern third of the basin, and southward where it dips under younger rocks.

4. Sandstone strata of Pennsylvanian age included within the Pottsville, Allegheny, and Conemaugh Formations throughout most of the Pennsylvania section of the basin, and especially along the southwestern divide.

5. The Chemung Formation of Devonian age along the New York-Pennsylvania State line.

In the northwestern part of the basin highly permeable outwash sand and gravel aquifers are underlain by water-yielding sandstones of the Pocono Formation of Mississippian age. This area appears to be particularly well suited for large-scale ground-water development. The Pocono also underlies permeable sand and gravel deposits in the valley of the Allegheny River from Tionesta to the mouth of Mahoning Creek, and this reach of the valley hence appears to be particularly well suited for large-scale water developments.

Throughout the basin, ground water high in iron poses a development problem. The extensive use of the water in most areas will necessitate iron-treatment facilities. South of the Clarion River most of the water-bearing sandstones are interlayered with productive coal seams. Contamination of the water resulting from coal mining is probably the major water problem in the basin. In addition, where the sandstones are tapped for water at depths in excess of several hundred feet, the water is highly mineralized. Therefore, except in the valley of the Allegheny River, there appears to be limited potential for extensive future development of ground water in the southern part of the basin.

PHYSIOGRAPHY AND DRAINAGE

The Allegheny River, headwater stream of the Ohio, rises at the western edge of the Allegheny Mountains in northwestern Pennsylvania. From here, the river flows in a great arc into New York State, and then back into Pennsylvania through important oil-producing areas. Above Warren, Pa., the Kinzua Dam, now under construction, will form a reservoir that will extend upstream to Salamanca, N.Y. The northwestern divide of the basin follows the crest of the Lavery Moraine (pl. 6), a ridge of glacial sediments parallel to and about 5 to 10 miles inland from Lake Erie.

From Warren, the river flows southwestward past Oil City to Franklin. From the source of the river near Coudersport to Franklin, the river flows near the southern limit of continental glaciation and rapidly attains major size as numerous streams draining the glaciated area to the north empty into it. Among the more important tributaries above Franklin are Olean, Conewango, Brokenstraw, Oil, and French Creeks. The valleys of Potato, Tunungwant, and Tionesta Creeks, which drain the unglaciated area south of the river, contain glacial outwash deposits, revealing that these streams near the northern boundary of Pennsylvania served as drainageways for glacial melt waters.

Downstream from Franklin, the Allegheny River follows the western divide of the Allegheny basin and all of the major tributaries, including the Clarion River; Redbank, Mahoning, and Crooked Creeks; and the Kiskiminetas River enter the river from the east. These westward-flowing streams drain the dissected coal-mining area of the Appalachian Plateau in western Pennsylvania and for the most part, the streams are entrenched into deep valleys cut into the bedrock formations underlying the Plateau. The valley of the Allegheny River is partly filled with glacial and alluvial sediments carried by the stream, which was a major drainageway for water melting from the glaciers to the north.

At Pittsburgh, 322 river miles from its beginning in Potter County, Pa., the Allegheny River is joined by the Monongahela to form the Ohio. The total area drained by the river is about 11,700 square miles, including 9,800 in Pennsylvania, and 1,900 in New York.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

Abundant supplies of ground water are available for development in the glaciated northern part of the Allegheny River basin (pl.6). As is typical in glacial terranes, the sources of water in the glacial deposits are irregularly distributed. The chief sources of ground water in the glacial drift are outwash deposits that fill the valleys of the major tributaries within the glaciated areas, and are interbedded within moraine and till-plain deposits elsewhere. Permeable outwash deposits are present also throughout the valley of the Allegheny River, and a few of its tributaries draining the unglaciated area in the northern part of the basin.

The outwash deposits in valleys of the major tributaries to the Allegheny vary in thickness from a few tens of feet to almost 500 feet (table 1). Some of the larger towns, such as Warren, Titusville, and Meadville in Pennsylvania, and Jamestown in New York, tap these outwash deposits for their public and industrial supplies. Yields of from 100 to 2,000 gpm (gallons per minute) are common from the outwash deposits. Such yields are possible because the outwash is very permeable and occurs in glacial drainageways now occupied by perennial streams that are sources of recharge to the aquifers.

The glacial and alluvial sediments in the valley of the Allegheny River are among the most important sources of ground water in the Allegheny basin. At Roulette, Pa., Lohman (1939) reported a yield of 465 gpm from a well drilled 126 feet into the sand and gravel. At Port Allegany, wells ranging in depth from about 100 to 250 feet, drilled into the Allegheny River alluvium, yielded about 250 gpm with very little drawdown. In New York, the river alluvium is also a potential source of water for various municipalities located along its banks, although the larger towns, such as Olean and Salamanca, obtain water from wells drilled into the outwash deposits along tributary stream valleys. Along some reaches of the river, however, wells are cased through the sand and gravel aquifers because of reported high iron content, and tap underlying sandstone strata.

Many of the larger cities downstream from the New York-Pennsylvania State line tap the alluvium. Numerous wells in Warren, Franklin, Ford City, and Pittsburgh, pump 100 to 1,000 gpm from the permeable sand and gravel deposits, which range in thickness from about 180 feet at Franklin to about 65 feet at Pittsburgh. In the Pittsburgh area, the width of the alluvial fill corresponds closely with the width of the present valleys.

TABLE 1.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS* OF THE CHIEF AQUIFERS OF THE ALLEGHENY RIVER BASIN.

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temperature (°F)
				Unconsolidated Deposits					
Glacial outwash in principal tributaries within glaciated area	0-480	16-210	0-20	36-280	1-120	1-50	.01-2.5	100-320	48-52
Allegheny River glacial and alluvial sediments	60-250	35-250	10-30	120-280	15-350	30-90	0-3.0	180-600	50-54
Glacial deposits in tributaries draining unglaciated area	0-300	36-260	5-30	45-220	6-42	5-70	.01-8.5	57-200	50-54
Glacial sediments within Kent and Lavery Moraines and intervening till plain	0-100±	12-100	--	100-270	19-75	4-22	.2-2.5	140-320	49
				Consolidated Deposits					
Pocono Formation	450-1400	63-810	0-100	10-170	4-100	2-160	0-6.8	22-580	49-52
Pottsville Formation	65-250	14-400	10-65	50-150	3-160	1-130	.05-19	74-570	50-53
Allegheny Formation	250-370	60-350	--	91-250	6-100	1-61	.03-8.9	38-400	50
Devonian (Chemung Formation only)	--	45-350	--	50-190	1-25	2-71	.04-1.5	140-320	48-54
Conemaugh Formation	500-750	60-200	--	100-330	3-80	3-25	.16-3.3	160-520	50-54

*Based on analyses of waters used for public or industrial supplies. Contaminated or saline water not included

The average width is somewhat less than 1 mile. The great volume of sediments contained in the lower Allegheny valley--and the availability of water from the river for recharge--provide for a manyfold increase in ground-water use in the Pittsburgh Metropolitan Area (Noecker, Greenman, and Beamer, 1954).

Little data are available concerning the hydraulic characteristics of the glacial and alluvial deposits in the valleys within the unglaciated area tributary to the Allegheny River. At Smethport, Pa., a well drilled into the alluvium along Potato Creek reportedly yielded about 50 gpm, and a well in the alluvium along Tunungwant Creek reportedly yielded 140 gpm. The fact that glacial and alluvial sediments are present in the valleys of Potato, Tunungwant, and Tionesta Creeks indicates a potential for ground-water development in the valleys of these streams.

Permeable sand and gravel is also interbedded with the less permeable sediments underlying the moraines and till plains within the area covered by the Wisconsin glaciers, but data concerning their areal distribution, depth, and hydraulic properties are not available for parts of the New York section of the basin. A few data are available for the area in Pennsylvania lying between the Lavery and Kent Moraines, where many domestic and small industrial wells yield 20 to 100 gpm of water from sand and gravel interbedded in the glacial till. The glacial drift deposited by the Illinoian glaciers south of the Kent Moraine probably would not yield supplies greater than those needed for domestic purposes, and perhaps none at all in the upland areas.

Bedrock Formations

The Allegheny River rises in a northeast-trending anticlinal ridge in Potter County, Pa., more than 2,500 feet above sea level. Near its source above Coudersport, the river is incised into rock strata of the Conewango Formation of Devonian age and is fed in part by water draining from the eroded remnants of the upper part of the Conewango rocks and sandstones of the Pocono Formation (pl. 7). In this area, wells about 120 to 220 feet deep obtain small yields from the sandstones. At Coudersport, wells drilled into the valley bottom to depths of about 200 feet obtain yields of as much as 200 gpm from the Devonian Chemung Formation (Lohman, 1939, p. 184). These wells are cased through more than 100 feet of glacial sand and gravel, which reportedly yields water high in iron content.

Municipal wells at Port Allegany are drilled through shales and siltstones of the Conewango Formation to tap the underlying Chemung Formation. Here six wells yield a total of 250 gpm, and one well reportedly yielded 250 gpm for 48 hours.

After the river swings northward toward the New York State line, it picks up considerable flow from springs and tributaries draining remnants of sandstone strata from overlying rocks of Mississippian and Pennsylvanian age. A few wells in New York are reported to have yielded as much as 25 gpm from the Chemung Formation.

In the New York portion of the basin, the river has cut through the sandstones and siltstones of the Conewango Formation, and flows over the Chemung Formation. Both of these rock units consist primarily of shale, and yield very little water. The Canadaway Group of Devonian age is the oldest rock unit forming the bedrock surface within the Allegheny basin. Some of the northernmost tributaries to the Allegheny River, including Cassadaga, Conewango, Ischua, and Oil Creeks are in valleys that are eroded through the overlying Chemung Formation and flow on the Canadaway Group. Because the glacial drift is such a prolific source of ground water in much of the New York section of the basin, and the Devonian rock strata--with the exception of the Chemung Formation--generally are poor water-bearers, there appears to be limited potential for large-scale developments of ground water from units of the Devonian System. (Plate 7 classifies the entire area where the Devonian rocks form the bedrock surface as one where only small yields can be obtained from consolidated rock aquifers. The Chemung Formation within the Devonian System is capable of yielding large quantities of water to wells in some localities as described above, but inadequate data are available on which to delineate the area of the basin over which high yields can be obtained from the Chemung.)

As the river re-enters Pennsylvania, it flows southwestward through Warren to Franklin. The upper one-third of this reach of the river has eroded through the rock units of the Conewango Formation, and flows in a glaciated valley cut into the underlying Chemung rocks.

The principal sources of water from the bedrock formations in the northern tier of counties in Pennsylvania are wells drilled into the upper part of the Chemung Formation. Some of these wells were originally drilled for oil but were plugged at appropriate depths to convert them to water producers. Yields from these wells are generally quite small.

Sandstone units of Mississippian age are a source of water in much of the upland area in the northern part of the basin. In this area the Pocono Formation is reported to be more than 300 feet thick, and consists of massive and thin-bedded sandstones interbedded with shales and a few thin beds of limestone. In western Pennsylvania, the Pocono sandstones are widely referred to as the "Mountain Sands". At Oil City, municipal wells drilled into these rocks yielded 300 to 2,000 gpm. An industrial well at Franklin tapping the same rocks pumped 2,100 gpm. One spring near Meadville, Pa., issuing from this formation, was reported to flow at about 280 gpm, and a few wells tapping these units along the valley of the Clarion River yielded more than 100 gpm (Leggette, 1936).

In the southern part of the basin, the Pocono Formation ranges from 450 to 1,400 feet in thickness. Where the Pocono is encountered at depths greater than about 200 feet, the water is likely to be highly mineralized.

Massive sandstone units of the Pottsville Formation of Pennsylvanian age are sources of small to moderate supplies of water throughout much of its outcrop area north of the Clarion River. In many places, however, and especially along the Clarion River valley, and the valley of the Allegheny between Tionesta and Emlenton, sandstones of the underlying Pocono have much higher yields. At Punxsutawney, however, Leggette (1936, p. 165) reported that a well drilled 156 feet into the Pottsville yielded 313 gpm. It may be that the sandstone in this area is fractured and readily recharged by Mahoning Creek.

South of the Clarion River, sandstone layers within the Allegheny Formation are the chief sources of ground water from the bedrock. In the general area lying between the Clarion River and Mahoning Creek, the Allegheny Formation is the principal source. Most of the rock units of this formation are shale, and only the massive sandstone units are reliable sources of water. Wells in Clarion and Jefferson Counties tap sandstone

units of the Allegheny. Some wells penetrate the Allegheny and tap the underlying Pottsville Formation. Sandstones of the Allegheny Formation are also sources of supply in Armstrong and Indiana Counties, and in some cases to wells south of Mahoning Creek drilled through parts of the overlying Conemaugh Formation. The Allegheny Formation is about 300 to 360 feet thick where the entire section is present. Although the sandstones of the Pottsville and Allegheny Formations will yield moderate supplies of water, the water is likely to be high in iron and salty where encountered below regional drainage level.

Shale, sandstone, and coal layers of the Conemaugh Formation form the bedrock surface over most of the Allegheny basin lying south of Mahoning Creek. Sandstone units of the Conemaugh in this area are the principal sources of ground water for domestic, small public-supply, and industrial wells over large areas of Armstrong, Indiana, Westmoreland, Cambria, and Somerset Counties. Large supplies of ground water are not generally available from this formation. Within the area covered by Conemaugh rocks, some large ground-water supplies have been obtained by wells drilled through the Conemaugh and Allegheny Formations into underlying sandstone units of the Pottsville Formation. In the Conemaugh River basin, especially along the front of the Allegheny Mountains, Pottsville sandstone units apparently are far more productive than in the outcrop area in the north-central part of the basin. Near Windber, one well tapping sandstones of the Pottsville and sandstone members of the Mauch Chunk Shale of Mississippian age, was reported to have yielded 570 gpm (Lohman, 1938, p. 286).

The youngest rocks forming part of the bedrock surface in the Allegheny basin are units of the Monongahela Formation. These rocks are present over significant areas only in Westmoreland County at the southern edge of the basin. The formation includes layers of coal, limestone, and sandstone, but yields very small quantities adequate only for domestic supplies. About 25 gpm is the maximum reported yield to wells from the Monongahela Formation, but even this amount is not obtainable where the sandstones are overlain by less permeable rock or a thick soil mantle. The water from shallow zones is hard and moderately mineralized, but the mineral content increases with depth.

CURRENT STATUS OF GROUND-WATER INFORMATION

The Pennsylvania section of the Allegheny basin is covered by four rather detailed regional reports on the ground-water resources. These reports were published during the 1930's, and the data contained in them reflect the nature of ground-water development three decades ago. For example, these reports show that in the 1930's prolific glacial drift aquifers were left untapped in favor of much smaller sources because of "high iron" concentrations, whereas with today's technology, treatment for removal of iron is a common practice. References were made to mine contamination, but its importance and its adverse effects on the total resource were not stressed due to the limited economic role of water during and before the period of the investigations. These reports provide a wealth of hydrogeologic information that is of lasting value; however, future development will require more detailed geochemical and quantitative hydraulic appraisals.

The ground-water situation in the Pittsburgh area (Noecker, 1954) is rather adequately covered by a Geological Survey report on the overall water resources of the area, and by a report on the ground-water resources in the valley fill in Allegheny County (Adamson, 1949).

Published data specifically covering the ground-water resources in the New York section of the basin are as yet rather sparse, but many of the interpretations in this report were made possible by use of geologic maps published by the State Museum and bulletins on water quality published by the State Health Department.

Bibliographic citations for the more significant reports containing information on the ground-water resources in the Allegheny basin are as follows:

Adamson, J.H., Graham, J.B., and Klein, N.H., 1949, Ground-water resources of the valley-fill deposits of Allegheny County, Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-8, 181 p., 5 pls., 9 figs.

Beetem, W.A., 1954, Chemical quality of water resources of the Conewango Creek basin, New York: New York Dept. Commerce Rept., 58 p., 8 figs.

Heath, R.C., 1964, Ground water in New York: New York Conserv. Dept. Bull. GW-51.

Leggette, R.M., 1936, Ground water in northwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-3, 215 p., 9 pls., 15 figs. (Covers Armstrong, Clarion, Crawford, Erie, Forest, Indiana, Jefferson, Mercer, Venango, and Warren Counties.)

Lohman, S.W., 1938, Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-5, 315 p., 17 pls., 11 figs. (Covers Cambria, Clearfield, and Somerset Counties.)

______ 1939, Ground water in north-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-6, 219 p., 9 pls., 13 figs. (Covers Elk, McKean, and Potter Counties.)

Noecker, Max, Greenman, D.W., and Beamer, N.H., 1954, Water resources of the Pittsburgh area, Pennsylvania: U.S. Geol. Survey Circ. 315, 56 p., 2 pls., 37 figs.

Pauszek, F.H., 1956, Chemical quality of water resources in the Allegheny River and Chemung River basins, New York: New York Dept. Commerce Rept., 44 p., 8 figs.

Piper, A.M., 1933, Ground water in southwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-1, 406 p., 1 pl., 40 figs. (Covers Allegheny, Butler, and Westmoreland Counties.)

Shepps, V.C., and others, 1959, Glacial geology of northwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. G-32, 59 p., 1 pl., 5 figs.

MANAGEMENT CONSIDERATIONS

There is a great potential for the development of ground water adequate for municipal, industrial, irrigational, or other large uses in the northern half of the Allegheny basin. Throughout most of this area ground water is available from either unconsolidated sediments or the bedrock formations, and in some instances from both sources. Quite probably the greatest potential for large-scale development exists in Crawford, Warren, and Venango Counties, Pa., where excellent glacial aquifers overlie permeable bedrock aquifers. The streams draining the glaciated area, especially the Allegheny River itself, have considerable water-yielding potential and also are available sources of recharge for streamside aquifers.

Although there appear to be very few problems in locating adequate quantities of supply in the northern part of the Allegheny basin, quality problems do exist. In this area, numerous oil wells have been drilled in the past century. Some of the high-chloride waters in a few streams and rather shallow aquifers undoubtedly originated from oil- and gas-bearing formations. A detailed study would be required to accurately delineate areas where contamination of water-bearing formations by brines would prevent or impede future ground-water development. Also, many of the permeable sandstones encountered at more than 200 feet in depth yield water with objectionably high chloride concentrations, and closer study of hydrochemical conditions should precede future developments.

With the exception of the valley of the Allegheny River, the potential for large-scale development of ground-water resources south of the Clarion River is far less favorable. Most of this area is underlain by layers of slightly to moderately permeable sandstone. Only in the head-waters area of the Conemaugh River are large yields available from the sandstones. It is quite likely that large yields of water may be available at depth from one or more of the numerous sandstone units in some localities. Most wells tapping the deep sandstone formations in the southern part of the basin, however, yield water too highly mineralized for most uses.

An even more serious problem in the southern part of the basin is the pollution associated with coal mining. When water in the presence of air comes into contact with sulfur-bearing minerals in and adjacent to coal seams--either in surface strip mines or underground workings--sulfuric and other acids are formed. The area has been intensively mined for coal for more than a century so that conditions resulting in the movement

of acid waters into the streams and into sandstone aquifers underground are quite prevalent. While the problems resulting from strip mining might be reduced by reclamation practices, a feasible solution to discharge from underground mines does not appear to be on the horizon. The answer to such problems, at least for the foreseeable future, lies in the treatment of these waters. On the other hand, where water in sandstone aquifers has not been in contact with the atmosphere in its movement underground, acidity is not a problem.

Specific water-resources developments based on ground-water exploitation must be preceded by detailed geochemical studies to insure obtaining ground water of suitable quality. Such studies will be complex and costly, because of the natural limitations on quantity and water-quality problems in the southern half of the basin. The greatest promise for ground-water development in the Allegheny basin, therefore, lies in the area north of the Clarion River.

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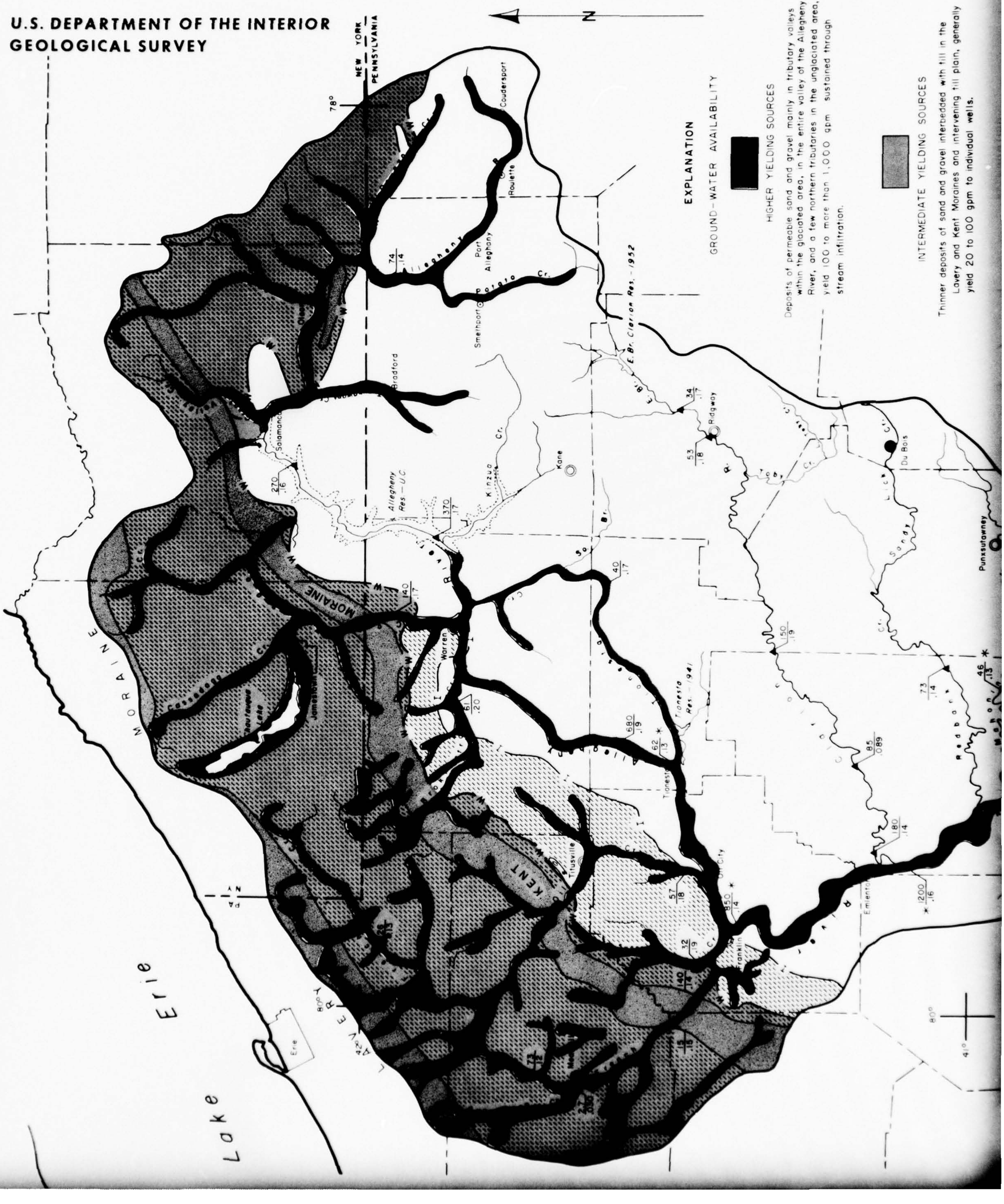

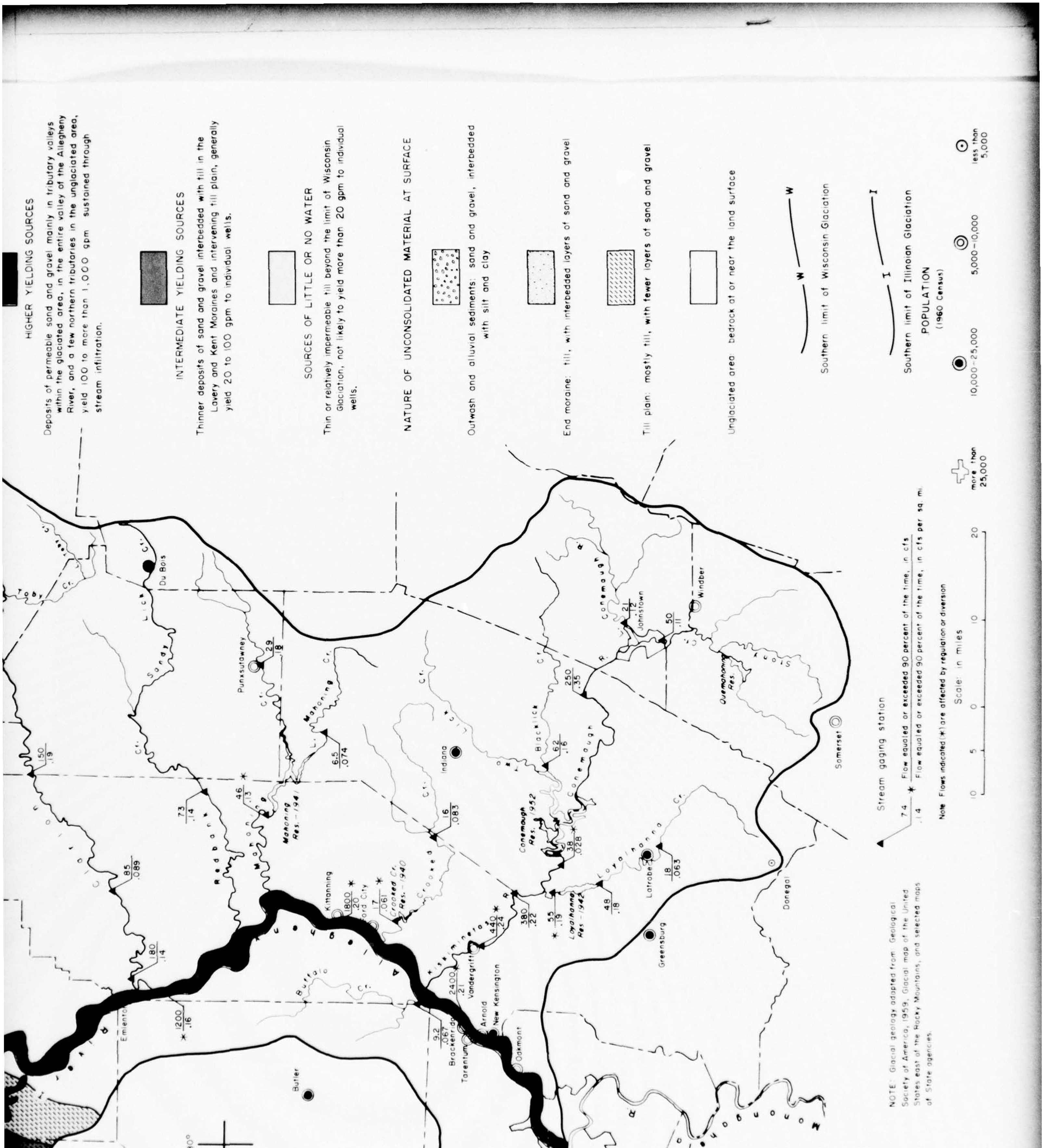

ALLEGHENY RIVER BASIN
SOURCES OF GROUND WATER IN UNCONSOLIDATED SEDIMENTS

PLATE 6

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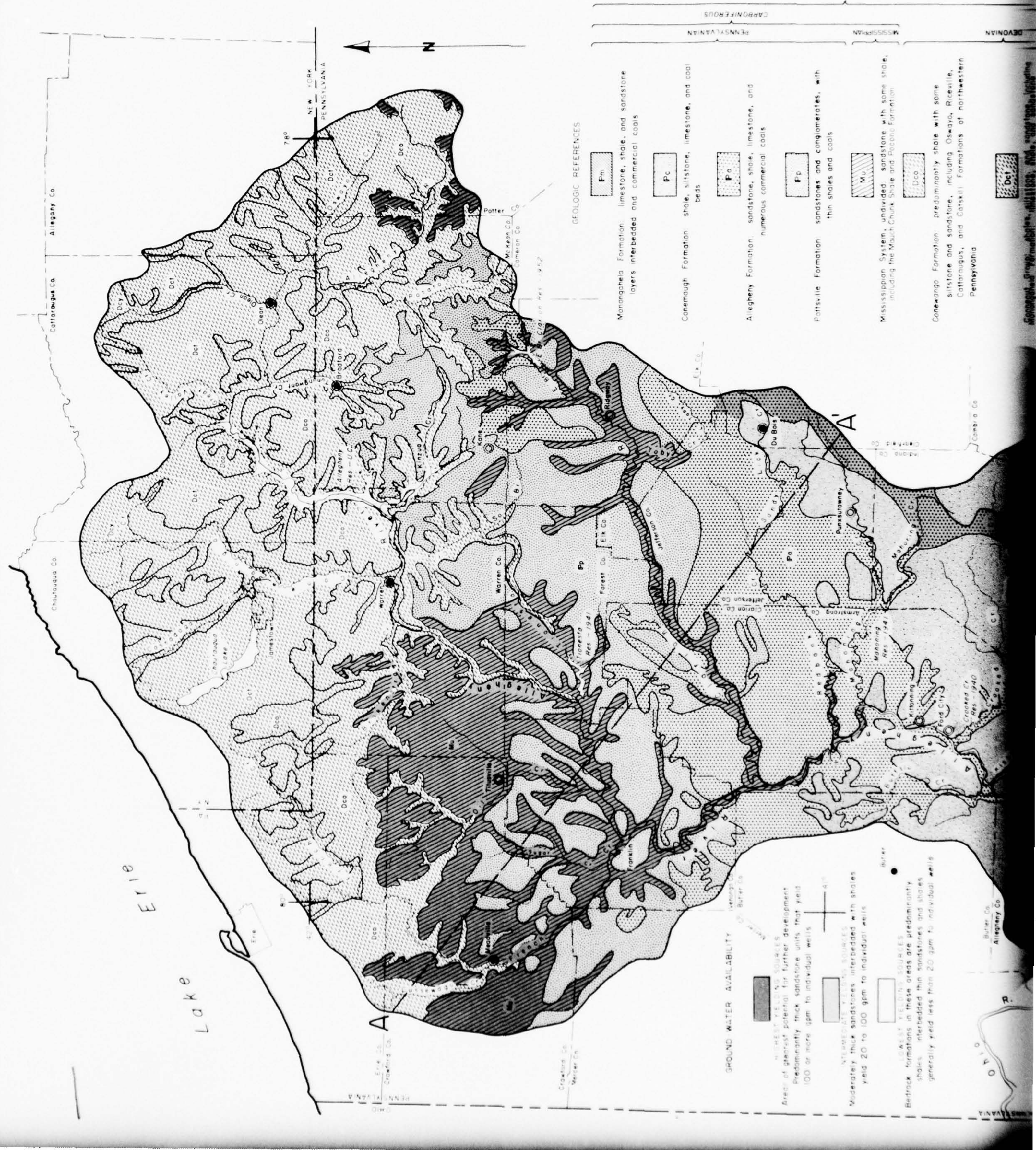

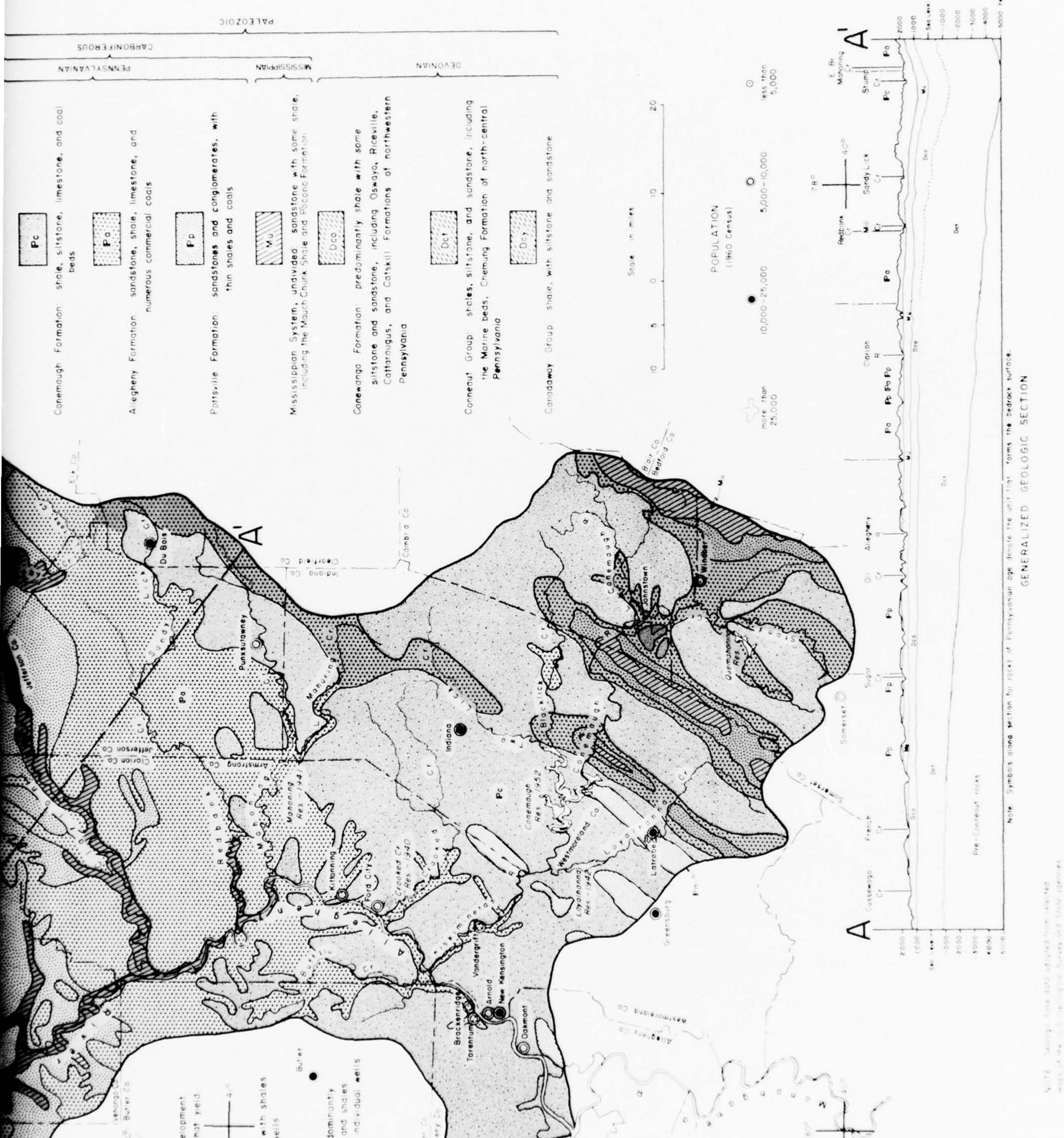

ALLEGHENY RIVER BASIN
SOURCES OF GROUND WATER IN BEDROCK FORMATIONS

PLATE 7

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 2

MONONGAHELA RIVER BASIN

By

Paul R. Jordan and George D. Dove

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

MONONGAHELA RIVER BASIN

CONCLUSIONS

The Monongahela River basin contains several areas in which large supplies of ground water are available for further development. These areas are mainly in the eastern mountainous part of the basin, where demand for water supplies has been small inasmuch as this area is relatively undeveloped. Large supplies are also available to the many industries and towns along the lower Monongahela and Youghiogheny Rivers, but these supplies require very careful development to avoid contamination by acid and by salts. In the central part of the basin, where more industries and large towns are located, large supplies of ground water are available, but their distribution is erratic, and more detailed exploration is required to delineate areas of large ground-water yields. In the western third of the basin, there are no known sources of large ground-water supplies; development of dependable or large supplies of water in this portion of the basin would require construction of surface reservoirs.

The chief sources of ground water in order of estimated decreasing potential, and their general locations, are as follows:

1. Sandstone aquifers of the Pottsville Formation, often in combination with sandstone of the Allegheny Formation, in three major northeast-southwest bands running roughly from Donegal, Pa. to Colfax, W. Va.; from Somerset, Pa. to Pickens, W. Va.; and from Davis, W. Va. to Valley Head, W. Va.

2. Alluvium along the Monongahela River from Brownsville to Pittsburgh and along the Youghiogheny River from West Newton to McKeesport.

3. Sandstone aquifers of the lower part of the Conemaugh Formation in a wide band, interrupted in places by older and younger rocks, across the central part of the basin from northeast to southwest.

4. Sandstone aquifers of Devonian age, particularly along the courses of the Tygart Valley River and Cheat River from Valley Head through Elkins and northeastward into Maryland to the vicinity of the Deep Creek Reservoir.

Ground water from most of the chief sources generally contains iron in objectionable concentrations. Aside from the iron, the water from the sandstone aquifers is of good quality; it has not generally been affected by acid, even though mines in the same formations discharge highly acidic water to the streams. Water in the alluvium can become contaminated in places by salts dissolved from the blast-furnace slag of steel-producing plants. Although the alluvium is recharged by acidic water from the Monongahela and Youghiogheny Rivers, the water pumped from wells has been nearly neutralized by carbonate compounds probably derived from limestone strata in the adjacent bedrock formations, from the alluvial sediments themselves, or from lime-treated waters wasted from industrial plants.

PHYSIOGRAPHY AND DRAINAGE

The headwater stream of the Monongahela basin, the Tygart Valley River, rises in eastern West Virginia near the eastern edge of the Appalachian Plateau, and flows northward. The Buckhannon River, which drains a part of the dissected and rugged Plateau, flows into the Tygart Valley River from the west above Philippi. At Grafton, the river is dammed to form the Tygart Lake. The southwestern part of the basin is drained by the West Fork River, which also flows northward and joins the Tygart Valley River at Fairmont, W. Va., to form the Monongahela. At Point Marion, Pa., a few miles below the West Virginia State line, the Cheat River empties into the Monongahela from the southeast after having drained about 1,400 square miles of the eastern part of West Virginia. This part of West Virginia lies in the Allegheny Mountains along the edge of the Valley and Ridge Province.

Although the headwater stream of the Cheat River, Shavers Fork, rises only a few miles east of the Tygart Valley River, it is interesting to note that it does not empty into the waters of that stream until it reaches Point Marion, more than halfway to Pittsburgh. This is due to the strong control exerted by the folds of the mountains where the ridges and the major stream valleys trend in a northeast-southwest direction parallel to the tighter folds of the Valley and Ridge Province. Similarly, the Youghiogheny River, which drains the westernmost part of Maryland, flows northeastward along the bedrock folds to the Pennsylvania State line. A dam at Confluence, Pa., has created the Youghiogheny River Reservoir of Pennsylvania and Maryland. Below Confluence, the river flows northwestward across the Alleghenies and empties into the Monongahela at McKeesport. A few miles downstream, at Pittsburgh, the Monongahela joins the Allegheny River to form the Ohio. The total area drained by the Monongahela River is 7,340 square miles. The maximum dimensions of the basin are roughly 130 miles south to north, and 75 miles east to west along the southern boundary of Pennsylvania.

SOURCES AND DISTRIBUTION OF GROUND WATER

The Monongahela basin is underlain by Paleozoic sedimentary rocks (pl. 8). The oldest rocks forming the bedrock surface are of Devonian age. These are found in the mountains of the eastern part of the basin. In the central and western part of the basin, the rocks of the Appalachian Plateau generally dip toward the northwest where progressively younger rocks are present at the surface. Most of the surficial rock formations are composed of alternating layers of sandstone, shale, and coal. Limestone crops out in narrow northeast-southwest trending belts in the eastern third of the basin.

The western part of the basin is underlain by rocks of the Dunkard Group of Pennsylvanian and Permian age, and the Monongahela and Conemaugh Formations of Pennsylvanian age. With the exception of the lower parts of the Conemaugh, these formations consist largely of shale, and fine-grained sandstone beds which yield only small amounts of water to wells and streams. The central and eastern parts of the basin are underlain by water-yielding coarse-grained sandstones and cavernous limestones of the Pottsville, Allegheny, and Pocono Formations, and the Greenbrier Limestone.

Alluvium is present in all the major stream valleys, but is a source of significant amounts of water only along the lower reaches of the Monongahela and Youghiogheny Rivers above Pittsburgh.

Unconsolidated Sediments

River alluvium along the lower reaches of the Monongahela and Youghiogheny Rivers consists of alternating layers of sand and clay to a depth of 30 to 40 feet below the natural flood plains. This sand and clay is in turn underlain by 20 to 50 feet of poorly sorted sand and gravel. It is from these sand and gravel deposits that the largest supplies of ground water from the alluvium are obtained. At several places downstream from Clairton, Pa., the alluvium carries an overburden of as much as 30 feet of blast-furnace slag.

Yields of 300 gpm can be obtained from the river alluvium along the Monongahela River from Brownsville to Pittsburgh and along the Youghiogheny River from West Newton to McKeesport. Large yields from the alluvium have been sustained for long periods without excessive drawdowns because river water infiltrates through the alluvium to the wells. Static water levels in wells drilled into the alluvium are typically about 15 to 35 feet below land surface (see table 2 for other hydraulic and chemical characteristics).

Because of contamination by river water and by salts from blast-furnace slag, the quality of water in the alluvium is rather variable. The only consistent characteristic seems to be the presence of undesirably high concentrations of iron.

Analyses of water from two wells at Duquesne, Pa., show the variability of the water in the alluvium. Water from one of the wells had a hardness of 120 mg/l, total dissolved solids content of 300 mg/l, and sulfate and chloride contents below the limits suggested for drinking water by the U.S. Public Health Service. The iron content, however, was 4 mg/l. Water from the other well, which was drilled through 30 feet of slag into the alluvium, was of good quality when it was first tested, but in 10 days of pumping the hardness increased to more than 1,300 mg/l. The probable reason for the deterioration in quality of the water from the second well was the mineralization by the slag of water percolating through it. The slag contains large quantities of calcium and sulfate that are easily dissolved by water of low pH.

The Monongahela River at Charleroi, Pa., has a pH of less than 4.9 more than 90 percent of the time, and the Youghiogheny River at Suterville has a pH of less than 5.7 more than 90 percent of the time. However,

under existing pumping rates, the alluvial sediments, limestone strata in adjacent bedrock formations, or lime-treated industrial wastes are apparently able to supply enough neutralizing carbonate compounds to raise the pH of the ground water to about 6.8 or 7. It is possible that local heavy pumping for a long duration could result in the ground water having a low pH.

Bedrock Formations

Rocks of the Pottsville and Allegheny Formations are as much as 1,300 feet thick, and are composed principally of coarse-grained sandstone and conglomerate interspersed with thin beds of coal, shale, fire clay, and limestone. The sandstone of the Pottsville Formation is poorly cemented and, in places, extensively fractured and, therefore, is an important aquifer. In areas where the Pottsville is overlain by the Allegheny Formation, wells drilled to the Pottsville obtain part of their yield from the Allegheny. The Allegheny Formation is more tightly cemented and less fractured than the underlying Pottsville, and it thus stores and transmits water less freely.

The Pottsville and Allegheny Formations are at the surface in three north-south trending bands running roughly from Donegal, Pa. to Colfax, W. Va.; from Somerset, Pa. to Pickens, W. Va.; and from Davis to Valley Head, W. Va. (pl. 8). Throughout these areas, the Pottsville, alone or combined with the Allegheny Formation, will generally yield more than 100 gpm to wells, and reportedly yields more than 300 gpm to some wells. In the area between Davis and Valley Head, these formations are virtually untested for yield; however, the high dry-weather flows of Shavers Fork at Parsons, Blackwater River at Davis, and Cheat River near Parsons indicate that the Pottsville and Allegheny Formations are contributing significant quantities of water to the streams. In the outcrop areas of the Pottsville Formation wells range from about 100 to 250 feet deep, but where it is overlain by rocks of the Allegheny Formation, high-yielding wells are typically from 200 to 250 feet deep. The static water level is generally within 100 feet of the land surface.

Coal is mined extensively from both the Pottsville and Allegheny Formations. Drainage from both active and abandoned coal mines contributes acid loads to the nearby surface streams. Consequently, many streams have pH values of 2 to 4 during periods of low flow. Low pH values, however, have not been detected in water samples taken directly from wells. This is probably because of the absence of oxygen in the ground water necessary to form the acid.

Ground water from the Pottsville and Allegheny Formations near the outcrop areas is of good quality except for the presence of undesirable concentrations of iron. Treatment for removal of the iron will be necessary before the water may be used for most purposes. The water commonly has a hardness of less than 100 mg/l, a total dissolved mineral content of less than 500 mg/l, and negligible sulfate and chloride concentrations. Although the water from these formations is of good chemical quality near the outcrop

areas, mineral content increases as the formations dip northwestward under younger rocks. In northern West Virginia, good yields of fresh water can be obtained from the Pottsville Formation as far west as the Monongahela River. A few miles west of the river, however, the water is too mineralized for normal use. Wells obtaining fresh water from the Pottsville Formation near the Monongahela River range in depth from about 600 to 1,100 feet near Morgantown. In Pennsylvania, wells that obtain water from the Pottsville Formation from depths greater than 100 feet below the level of major streams generally obtain salty water. The most significant hydraulic and chemical characteristics of water in the Pottsville and Allegheny Formations are summarized in table 2.

In the eastern and southeastern part of the basin, yields of 20 to 100 gpm of water can be obtained from sandstones and limestones of Devonian and Mississippian age. Devonian rocks crop out in a large area along the course of the Tygart Valley River between Valley Head and Elkins, and along Shavers Fork and the Cheat River between Bowden and Rowlesburg. Mississippian rocks, principally the Pocono Formation and Greenbrier Limestone, crop out in long narrow belts on the flanks of the folded Devonian rocks. The Greenbrier Limestone is cavernous and numerous springs issue from it. Some wells in the Greenbrier Limestone produce more than 100 gpm of water. Most wells drilled into the Devonian and Mississippian rocks in the area are less than 200 feet deep. Deeper rocks in the area have not been tested either for yield or chemical quality. The Mauch Chunk Formation also crops out in long, narrow belts in this part of the basin. The Mauch Chunk consists mostly of shale and yields only enough water for domestic use. The Greenbrier Limestone and Pocono Formation underlie the Mauch Chunk and could conceivably yield as much as 100 gpm of water to wells; however, no wells have tapped these formations in this area so the quality of the water is unknown.

In the west-central part of the basin, yields of more than 20 gpm are obtained from the Conemaugh Formation, which is as much as 600 feet thick. The upper beds of the formation are much finer grained and contain more shale than the lower beds. The lower beds of the Conemaugh Formation contain coarse-grained sandstones that are extensively fractured, and wells drilled into these layers yield as much as 100 gpm of water. West of Fairmont and near Clarksburg, water from wells deeper than 200 feet is known to be highly mineralized.

TABLE 2.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE MONONGAHELA BASIN.

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Yields of high-capacity wells (gpm)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temperature (°F)
Pottsville and Allegheny Formations[a]	100-300	100- 500[b] 400-1100[c]	0-150[b] 50-500[c]	20- 100	1- 30	1- 30	0.3-6	50- 250	50-57
River alluvium	100-300	50- 130	15- 35	120-1700	50-1500	20-350	1-120	300-3000	53-67
Lower part of Conemaugh Formation[a]	50-200	80- 250	10- 50	30- 350	10- 150	5- 60	0.3-3	200- 700	50-56
Devonian rocks[a]	20-150	80- 200	0- 40	10- 130	0- 30	10-250	0.2-0.9	100- 600	53-58

[a] Highly mineralized water from great depths in the western part of the basin is not included in this table.
[b] In the outcrop area
[c] Where the Pottsville and Allegheny are overlain by the Conemaugh Formation

The western part of the basin is underlain by rocks of the Dunkard Group and the Monongahela Formation. The Monongahela ranges in thickness from a feather edge near Buckhannon, W. Va., to more than 600 feet thick along its boundary with the Dunkard Group. Both the Dunkard Group and Monongahela Formation consist largely of shale and therefore yield very small quantities of water to wells and to the streams. Streams draining these rocks have the lowest dry-weather yields in the basin. Wells drilled through the Monongahela Formation to the underlying Conemaugh Formation would be expensive and the water is almost certain to be highly mineralized.

CURRENT STATUS OF GROUND-WATER INFORMATION

Slightly more than half of the basin area is covered by fairly detailed reports on ground-water resources. The Pennsylvania portion of the basin is covered by two regional reports, published in 1933 and 1938, and a supplement on the valley-fill deposits of Allegheny County, published in 1949. The area in Maryland is covered by a report on Garrett County, published in 1954. Reports on Monongalia and Harrison Counties, W. Va., were published in 1958. Also, a more general report on the water resources of the state of West Virginia has a section on the ground water of the Monongahela basin in that state.

Bibliographic citations for the more significant ground-water reports in the basin are as follows:

Amsden, T.W., Overbeck, R.M., and Martin, R.O.R., 1954, Geology and water resources of Garrett County: Maryland Dept. of Geology, Mines and Water Resources Bull. 13.

Beamer, N.H., Greenman, D.W., and Noecker, Max, 1954, Water resources of the Pittsburgh area, Pennsylvania: U.S. Geol. Survey Circ. 315.

Carlston, C.W., 1958, Ground-water resources of Monongalia County, West Virginia: West Virginia Geol. and Econ. Survey Bull. 15.

Doll, W.L., Meyer, Gerald, and Archer, R.J., 1963, Water resources of West Virginia: West Virginia Dept. of Natural Resources Rept.

Lohman, S.W., 1938, Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-5.

Nace, R.L., and Bieber, P.P., 1958, Ground-water resources of Harrison County, West Virginia: West Virginia Geol. and Econ. Survey Bull. 14.

Piper, A.M., 1933, Ground water in southwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-1.

In most of the Monongahela River basin needs for ground water have been small, so that it has been unnecessary to determine the hydraulic capabilities of the water-bearing formations for other than general interpretation of yield and quality. Therefore, available data, including the

present report, are adequate only for general planning purposes, and more detailed information concerning the hydraulic and geochemical properties of the water-bearing formations will be needed for specific developments. Currently, a water-resources study by the U.S. Geological Survey, in cooperation with West Virginia, is underway in the West Virginia portion of the basin.

More data are needed to determine the depths and yields of the consolidated aquifers within the basin. This is particularly true in the western third where the formations that comprise good aquifers in the eastern two-thirds of the basin dip beneath the low water-yielding Dunkard Group and Monongahela Formation. The feasibility of tapping deep formations in the western part of the basin cannot be determined without a background of this type of information. In addition, much information will be needed on the occurrence, degree of mineralization, and hydrogeologic factors controlling movement of saline waters in the basin.

Considerably more data are needed on the thickness, yield, and areal extent of the unconsolidated deposits along the lower Monongahela and Youghiogheny Rivers. Also, additional information is needed concerning the recharge-discharge relationship of these streams with the underlying alluvial deposits. This relationship is extremely important when it is considered that by far the largest requirements for municipal and industrial water uses in the entire basin are centered within a short distance of Pittsburgh, where the unconsolidated deposits comprise important potential aquifers. Especially important background information needed prior to development of the alluvial aquifers is hydrochemical data from which predictions might be made of the long-term beneficial effect of the buffering action of slag in the channels in neutralizing acid river water, as well as the detrimental effects of slag in contributing to the mineral load of the river water. The U.S. Public Health Service has made provision for further studies of ground-water quality in the Chio Basin during the 1965-68 fiscal-year period. These studies will help define the relationships of geochemistry and hydraulics with water quality in areas where the potential for ground-water development is feasible.

MANAGEMENT CONSIDERATIONS

Ground-water supplies are adequate for domestic use throughout most of the Monongahela basin. Ground water in volumes adequate for municipal, industrial, irrigational, or other large uses is potentially available only in the eastern two-thirds of the basin. The water is generally of good quality, with the exception of excessive iron concentrations, and is suitable for most purposes without costly treatment. Because of the availability of both surface and subsurface sources of water supply in this part of the basin, planning could proceed on the basic assumption that alternate possibilities for water-supply development exist. Selection of the source or combination of sources to be tapped for a particular development would depend on the nature of the demand and the volumes needed, and would be based mainly on economic or engineering feasibility.

In the western third of the basin there are no known sources of large ground-water supplies. Although the Conemaugh underlies the shallower bedrock throughout this area, large-scale tapping of the formation would be expensive because of the depth involved. Also, the chances of obtaining fresh water (less than 1,000 mg/l total dissolved solid content) would be very small. Any development of water supplies from deep formations would have to be done under exacting construction specifications designed to prevent the contamination of shallow fresh-water aquifers, despite their limited potential, by saline water leaking upward along the wells. This is especially true west of the Monongahela River in West Virginia where the Pottsville and Allegheny Formations occur at considerable depth, and probably contain saline water.

The streams in the western third of the basin--being fed during dry weather mainly by ground-water discharge--will ordinarily have small flows during summer and fall months. It is evident, therefore, that development of dependable or large supplies of water in this portion of the basin would require construction of surface reservoirs. The West Fork River Reservoir, authorized for construction by the Corps of Engineers, is an example of the type of water resource development particularly suitable for a relatively poor ground-water area.

In obtaining large supplies of water from the alluvium along the lower reaches of the Monongahela and Youghiogheny River, the location, construction, and total pumpage from wells drilled into the alluvium can have an important effect on the quality of water obtained, as described above. Plans for development of large water supplies from the alluvium must not be based solely on the volumes of streamflow available and the hydraulic characteristics of the alluvium, but must include adequate provision for quality control and monitoring.

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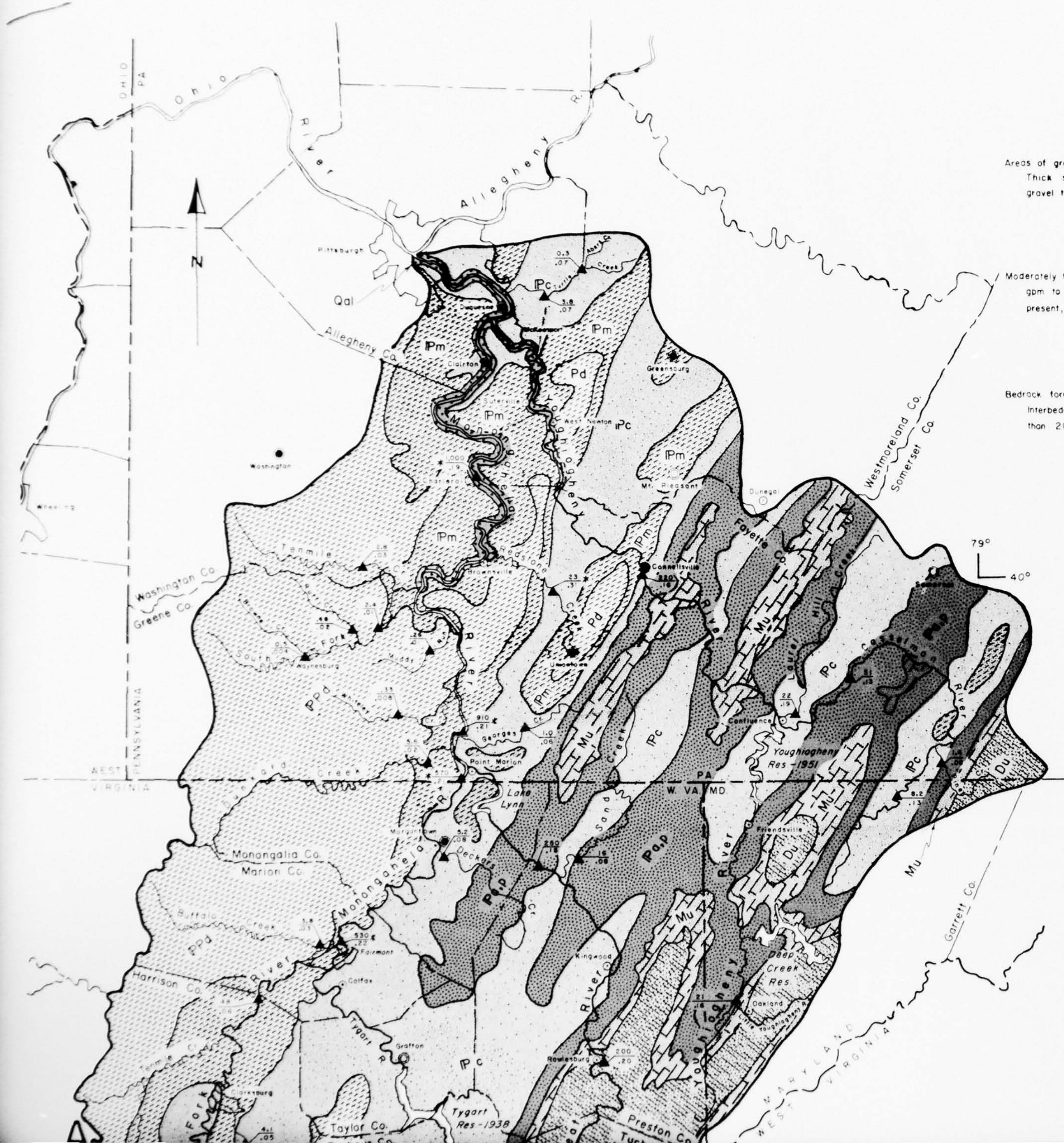


EXPLANATION

HIGHEST YIELDING SOURCES

Areas of greatest potential for further development. Thick sandstones and small areas of alluvial sand and gravel typically yield between 100 and 300 gpm to individual wells

INTERMEDIATE YIELDING SOURCES

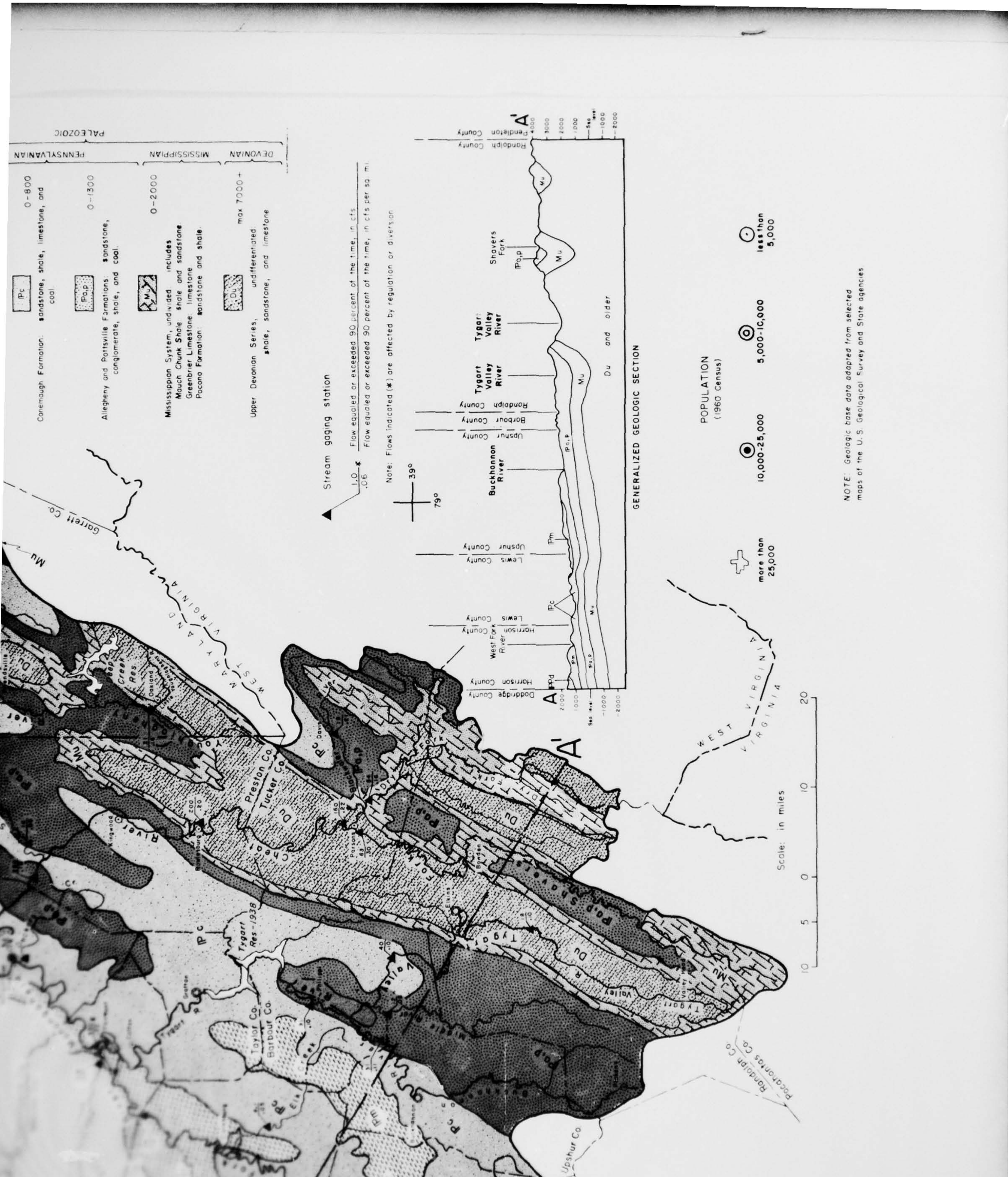
Moderately thick sandstones interbedded with shales yield 20 to 100 gpm to individual wells. Where cavernous limestones are present, some wells can obtain more than 100 gpm

LOWEST YIELDING SOURCES

Bedrock formations in these areas are predominantly shales. Interbedded thin sandstones and weathered shales yield less than 20 gpm to individual wells.

GENERALIZED GEOLOGIC REFERENCES

		Thickness, in feet		
Qal	Alluvial clay, silt, sand, and gravel underlying flood plains of the major rivers	0-90	QUATERNARY	
PPd	Dunkard Group: shale, sandstone, limestone, and coal.	0-1200	PENNSYLVANIAN and PERMIAN	PALEOZOIC
Pm	Monongahela Formation: shale, sandstone, limestone, and coal.	0-600	PENNSYLVANIAN	PALEOZOIC
Pc	Conemaugh Formation: sandstone, shale, limestone, and coal.	0-800	PENNSYLVANIAN	PALEOZOIC
Pa,p	Allegheny and Pottsville Formations: sandstone, conglomerate, shale, and coal.	0-1300	PENNSYLVANIAN	PALEOZOIC
Mu	Mississippian System, undivided: includes Mauch Chunk Shale: shale and sandstone; Greenbrier Limestone: limestone; Pocono Formation: sandstone and shale	0-2000	MISSISSIPPIAN	PALEOZOIC
Du	Upper Devonian Series, undifferentiated: shale, sandstone, and limestone	max 7000+	DEVONIAN	PALEOZOIC



MONONGAHELA RIVER BASIN
SOURCES OF GROUND WATER

PLATE 8

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 3

UPPER OHIO RIVER DRAINAGE AREA
(Area draining to the Ohio River between Pittsburgh and Marietta)

By

Paul R. Jordan

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

UPPER OHIC RIVER DRAINAGE AREA
(Area draining to the Ohio River between Pittsburgh and Marietta)

CONCLUSICNS

Supplies of ground water for future development are abundant along the Ohio River between Pittsburgh and Marietta, and in large portions of the Beaver and Mahoning River basins. The unconsolidated sediments in the valley of the Ohio River contain thick deposits of permeable gravel and sand, and the river provides a perennial source of recharge for streamside ground-water development. Bedrock and unconsolidated aquifers in the Beaver and Mahoning River basins generally provide smaller yields to individual wells, but they cover larger areas and thus are important sources of water for future development by smaller industries and municipalities.

The principal sources of ground water for future development in decreasing order of estimated potential are as follows:

1. Glacial and alluvial valley fill along the course of the Ohio River from Pittsburgh, Pa., to Marietta, Ohio.

2. Sandstone units of the Mississippian System where they form the bedrock surface in the northern parts of the Beaver and Mahoning River basins, and for an undetermined distance southward where they dip under younger rocks.

3. Sandstone units of the Pottsville and Allegheny Formations where they form the bedrock surface in the southern parts of the Beaver and Mahoning River basins, and for an undetermined distance southward where they, in turn, dip under younger rocks.

4. Glacial outwash deposits in the valleys of the Beaver and Mahoning Rivers and their major tributaries.

In the unglaciated southern two-thirds of the area covered by this report, the surficial bedrock formations are nearly all shale, from which only small supplies of water can be obtained. Large developments of water supplies in this area, therefore, will be possible only from surface sources or from unconsolidated sediments in the valley of the Ohio River.

Aside from the problem of locating sources of high ground-water yields, the main problems in the use of ground water are those associated with the quality of the water. Iron content in most of the ground water is higher than the limit suggested by the U.S. Public Health Service, and will cause

staining and other problems unless the iron is removed by aeration or other treatment. Wells in the Ohio valley fill commonly are useful for only 5 to 10 years because their screens become encrusted with calcium carbonate and iron. These problems have not, however, prevented the extensive use of ground water in the area. Nearly all the water from the principal aquifers has concentrations of sulfate, chloride, and total dissolved solids that are low enough to meet the standards suggested by the U.S. Public Health Service for drinking water.

PHYSIOGRAPHY AND DRAINAGE

The upper Ohio River drainage area as described herein consists of the area draining to the Ohio River between Pittsburgh and Marietta, Ohio--a distance of about 170 miles--and includes the Beaver and Mahoning River basins. The Ohio River flows entirely within the unglaciated part of the Appalachian Plateau. It flows northwestward from Pittsburgh in a highly industrialized valley, past Aliquippa, the largest municipality along this part of the river, to Monaca, Pa., where it is joined by the Beaver River and turns westward. The only large tributary between Pittsburgh and Monaca is Chartiers Creek, which has its headwaters near Washington, Pa., and drains a part of the unglaciated area.

The Beaver River drains the glaciated northern part of the Appalachian Plateau, and is formed by the confluence of the Shenango and Mahoning Rivers a few miles south of New Castle, Pa. The Shenango River flows out of Pymatuning Reservoir in the northernmost part of the area, and is joined by the Little Shenango River at Greenville, by Pymatuning Creek near Sharpsville, and by Neshannock Creek at New Castle. The Mahoning River has its origin upstream from Berlin Reservoir, in Ohio, and flows through the major industrial cities of Warren and Youngstown before entering Pennsylvania and joining the Shenango River. During dry weather, the natural flow from ground-water reservoirs into the Mahoning River and its tributaries is augmented by releases from Berlin and Milton Reservoirs on the Mahoning River, Mosquito Creek Reservoir, and Meander Reservoir. West Branch Reservoir, now under construction on the West Branch of the Mahoning River near Ravenna, when completed will also augment the dry-weather flow of the river.

Except for the drainage area of Connoquenessing Creek, the topography in most of the Beaver and Mahoning River basins and the drainage area of Little Beaver Creek is somewhat subdued because of the glacial processes that rounded many of the bedrock hills and filled most of the bedrock valleys with thick deposits of glacial sediments. Only thin deposits of glacial drift cover the bedrock highs within the glaciated area.

Downstream from the mouth of the Beaver River, the Ohio River flows westward and southward past the major industrial cities of Wierton, Steubenville, and Wheeling. This area has not been modified by glacial action, so the topography remains rather rugged and dissected; it is drained by many short streams in fairly deep, narrow valleys. These valleys contain negligible thicknesses of alluvial sediment, so the streams are flowing mainly on shale and sandstone bedrock formations. The last major tributary in the report area is the Little Muskingum River which empties into the Ohio upstream from Marietta.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

The northern part of the report area, including most of the area drained by the Beaver River, is underlain by glacial deposits ranging in thickness from a few feet to 350 feet or perhaps more. The drainage area of Connoquenessing Creek, a major tributary to the Beaver River, in northwest Pennsylvania, lies south of the limits of glaciation. Over most of the glaciated area outside the river valleys, glacial sediments have been deposited as till plains and end moraines (pl. 9) consisting of sand, gravel, and boulders imbedded in a matrix of clay. This material in most places has low permeability and is not a good source of ground water. In a few localities, small thicknesses of permeable sand and gravel are interbedded with till and yield moderate supplies of water, but these beds are irregularly distributed and have not been mapped in detail, so their location and extent cannot be shown on plate 9.

Long reaches of major stream valleys of the Beaver River basin, including those of the Shenango, Little Shenango, and Mahoning Rivers and Pymatuning, Neshannock, Meander, and Mill Creeks, are partially filled with glacial outwash. At some localities, the outwash is composed almost entirely of fine sand, which in the past has discouraged development, but elsewhere it contains numerous layers of sand and gravel that yield moderate to large supplies of ground water. In the favorable locations, yields of between 20 and 100 gpm have been obtained from the outwash. The water from these deposits is not extensively used for municipal or industrial supplies, probably because of the availability of adequate supplies from underlying bedrock aquifers and from the streams in the same area. A small town and an industry near Salem, Ohio, are supplied by wells yielding about 40 to 70 gpm, and an industrial well near Youngstown has about the same yield. Water discharging from the glacial drift also helps to sustain the dry-weather flow of the streams for water supply and waste assimilation, as shown on plate 9 for Little Shenango River at Greenville (0.11 cfs per square mile) and other unregulated streams draining the glaciated area.

The outwash in tributary valleys at a few places consists of rather thick beds of permeable gravel that are readily rechargable with surface water. This is shown by one of the wells that serves as a standby supply for the city of Alliance. The well was tested at 600 gpm (gallons per minute). Hydrologic and chemical characteristics of the valley-fill aquifers in tributary valleys, along with those of the other principal aquifers, are summarized in table 3.

TABLE 3.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE UPPER OHIO RIVER DRAINAGE AREA.

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (^{o}F)
Sand and gravel of Ohio River valley-fill deposits	10-40	100-1500	60-100	30-50	130-400	50-200	20-60	0.1-3.0	250-650	53-57
Sandstones of Mississippian System*	---	100-300	100-350	10-90	80-200	3-80	2-80	0.1-3.0	200-700	50-55
Sandstones of Pottsville and Allegheny Formations*	---	20-150	60-300	0-150	60-350	2-80	2-50	0.2-1.5	250-800	50-53
Sand and gravel of valley-fill deposits in Ohio River tributaries	---	20-100	60-140	10-50	---	---	5-50	0.3-3.0	200-600	51-56

*Data does not include analyses of highly mineralized water from great depths, nor water contaminated by oil-field brines or manmade wastes.

Available chemical analyses of water from outwash deposits in tributary valleys indicate that the dissolved-solids content normally is low enough to be acceptable for drinking water although the iron content is very likely to be higher than the recommended maximum. Little or no data concerning hardness, sulfate concentrations, and other mineral characteristics are available for large areas underlain by outwash deposits.

The Beaver River valley in the unglaciated area below the mouth of Connoquenessing Creek is filled with permeable glacial and alluvial sediments similar to those in the valleys in the glaciated area. Little use has been made of ground water from these sediments, probably because of the availability of water from the river and the lack of detailed knowledge of the distribution and permeability of the sediments.

The valley of the Ohio River from Pittsburgh to Marietta lies entirely outside the glaciated area, but contains glacial sediments transported by melt water streams in the Allegheny and Beaver River basins. This valley-fill material (pl. 9) is the most productive aquifer in the report area, and is the source of many large industrial and municipal water supplies. From Pittsburgh to Marietta, the valley is generally from 0.6 to 1.0 mile wide. In a few places the valley narrows to as little as 0.4 mile, and at Moundsville, W. Va., the valley attains a width of about 2 miles.

Although the sediments along the whole length of the river are capable of sustaining rather large yields of ground water, marked differences are found in the characteristics of this valley-fill material and in the hydraulic connection between the aquifer and the river. Thus, detailed hydraulic and geologic studies will be needed to determine the potential for development at specific locations where water facilities are planned or needed. Presently available published information, the most detailed of which is for the part of the valley that lies in West Virginia, indicates that the thickness of unconsolidated material in the valley ranges from 40 to 130 feet. The maximum thickness, however, includes sediments in terraces above the present river level that are not saturated and therefore not a source of ground water. The saturated thickness ranges from about 20 to 60 feet. Layers of clay and silt, reportedly ranging in thickness from a few feet to about 40 feet and averaging about 10 feet, are present beneath the flood plain throughout much of the valley from Pittsburgh to Marietta. In some places, these sediments act as a confining bed producing artesian conditions.

The permeability and thickness of the valley-fill sediments, and their hydraulic connection with the Ohio River, generally allows yields of more than 100 gpm to individual vertical wells. Many wells yield more than 300 gpm, and a few yield as much as 1,500 gpm. Because of the same favorable conditions, radial collector installations are used for several large industrial and public-water supplies. The West View Municipal Authority, which supplies water to a suburban area northwest of Pittsburgh, in 1946 was using about 57 vertical wells and one radial collector, all obtaining water from the valley fill. The vertical wells were being pumped at rates of about 200 to 1,000 gpm. A large number of industries in this same area, which is near Coraopolis, Pa., obtain their water supplies from the same deposits. In the vicinity of Moundsville, W. Va., vertical wells yielding about 750 gpm were being used for the public supply in 1954, and both vertical wells and radial collectors pumped water for industrial use.

The chemical quality of the water from the Ohio River valley fill (table 3) makes it suitable for most uses with a small degree of treatment. Dissolved-solids content is normally acceptable for drinking water, and concentrations of sulfate and chloride are less than the suggested maximum except in small areas where the water has been contaminated by waste discharges. The water generally would be classed as very hard and the iron content in many places is more than the 0.3 mg/l limit recommended by the U.S. Public Health Service for drinking water.

Although the Ohio River valley fill is presently being tapped for many large supplies of water, a large potential for future development remains. The ultimate potential of the aquifer cannot be calculated, owing to changes in pool level of the Ohio River and to inexact knowledge of the permeability and other characteristics of the aquifer throughout its length. A calculation of possible development for a section of the river near Moundsville, W. Va., was made by Carlston and Graeff (1955). They estimated that at least 26 mgd of ground water could be developed per mile of valley length along this section of the river. When yields of this magnitude are multiplied by the many miles of valley length between Pittsburgh and Marietta, the future potential far overshadows the 95 mgd of ground water pumped from this valley for all purposes in 1955.

Bedrock Formations

The upper Chio River drainage area is underlain by Paleozoic sedimentary rocks that dip very gradually toward the south. (See cross section on pl. 10.) Because these rocks lie nearly flat, they crop out, or are buried beneath glacial sediments, in wide bands across the area. The oldest rocks forming the bedrock surface are sandstones and shales of the Devonian and Mississippian Systems. They form the bedrock surface in the extreme northern part of the area (pl. 10). In the central part of the drainage area, the surface bedrock units of the Pennsylvanian System also consist largely of sandstones and shales, although thin limestone units are present in the geologic section. The rocks in the southern part of the area belong to the Pennsylvanian and Permian Systems and consist largely of shale.

Because the Devonian rocks are found in only a small part of the area and are overlain by water-yielding glacial deposits, little information is available concerning their water-bearing characteristics. Information from tests in nearby areas indicates that these rocks generally supply less than 20 gpm to individual wells.

Rocks of the Mississippian System include the Pocono Formation in Pennsylvania and Ohio. They consist chiefly of massive sandstone layers with some interbedded shale. Large yields of good water are generally obtained from these rocks in their outcrop areas and over an undetermined area where they dip beneath younger Pennsylvanian rocks. Hence, they are important sources of municipal and industrial supplies, particularly in areas where the overlying glacial drift does not include good aquifers. The largest reported yields from the Mississippian rocks are 750 gpm from an industrial well, and 600 gpm from a municipal well, both drilled through the Pottsville Formation into the Pocono Formation at Grove City, Pa. These yields, however, are exceptional. More common yields from these rocks are represented by the 75 gpm of an industrial well near Mosquito Creek Reservoir, and 180 gpm of an industrial well near Youngstown, Ohio. Water from wells in the Mississippian rocks normally meets the standards for drinking water except that in some places it has objectionable amounts of iron (table 3).

The Pennsylvanian rock system, for the purposes of this report, is divided into three hydrologic units--the Pottsville and Allegheny Formations, the Conemaugh Formation, and the Monongahela Formation. The Pottsville and Allegheny Formations are similar in lithologic and hydrologic character. They consist mainly of layers of sandstone and shale and hence are combined

into a single unit on plate 10. Both formations contain thin beds of coal, and the Allegheny Formation has a few limestone members. These formations are sources of municipal and industrial water supply in areas not accessible to water from the Ohio River or major tributaries. The town of East Palestine, Ohio, is in such an area, and obtains its water supply from wells that yield as much as 450 gpm. More typical of the Pottsville and Allegheny Formations is the 85 gpm yielded by a well that supplied a swimming pool at Butler, Pa. The dissolved-solids content of the water from these formations ranges widely, but generally is lower than the limit prescribed by the Public Health Service for drinking water. Sulfate and chloride concentrations in all the analyses inspected were below the limits for drinking water. However, the iron content shown in most of the analyses is high enough to require treatment for public-supply purposes.

The Conemaugh Formation, a thick unit consisting mostly of shale and sandstone, has been little used as a source of water, other than for domestic supplies. Yields of 20 to 50 gpm probably can be obtained from wells in the Conemaugh Formation, and in some localities larger yields can probably be obtained. The formation is little used because in the area where it forms the bedrock surface most large towns and industries obtain their water supplies from the Ohio River or from valley-fill aquifers.

The next two bedrock units that outcrop toward the south, the Monongahela Formation of the Pennsylvanian System, and the Dunkard Group of the Pennsylvanian and Permian Systems, consist mainly of shale, coal, and sandstone of very low permeability, and supply little water to wells. They also supply little water to the streams, as shown by the low flows on plate 9 for Wheeling Creek at Wheeling (0.02 cfs per square mile) and several other streams draining the Dunkard Group. The bedrock formations that are tapped for water supply in the northern half of the report area underlie the Monongahela Formation and the Dunkard Group at depths of about 500 to 2,000 feet, but any water at these depths is very likely to be too highly mineralized for most uses.

CURRENT STATUS OF GROUND-WATER INFORMATION

A large part of the report area is covered by fairly detailed reports on ground-water resources. The Pennsylvania portion of the area is covered by two regional reports, published in 1933 and 1936, a detailed report on Beaver County, and a report on the valley-fill deposits of Allegheny County. A detailed report on Ohio County, West Virginia, was published in 1964, and the Ohio River valley fill in West Virginia is covered by a detailed report published in 1955. In addition, a general report on the water resources of West Virginia has a section on ground water in the drainage areas of the minor tributaries of the Ohio River. The area in Ohio is covered by reports on the Mahoning River basin and by maps of ground-water availability, published as part of the Ohio Water Plan Inventory.

Bibliographic citations for the chief sources of ground-water information for areas of county-size or larger are as follows:

Adamson, J.H., Jr., Graham, J.B., and Klein, N.H., 1949, Ground-water resources of the valley-fill deposits of Allegheny County, Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-8, 181 p.

Carlston, C.W., and Graeff, G.D., Jr., 1955, Ground-water resources of the Ohio River valley in West Virginia: West Virginia Geol. Survey vol. XXII, part III, 131 p.

Cross, W.P., Schroeder, M.E., and Norris, S.E., 1952, Water resources of the Mahoning River basin, Ohio, with special reference to the Youngstown area: U.S. Geol. Survey Circ. 177, 57 p.

Doll, W.L., Meyer, Gerald, and Archer, R.J., 1963, Water resources of West Virginia: West Virginia Div. Water Resources, 134 p.

Leggette, R.M., 1936, Ground water in northwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-3, 215 p.

Ohio Division of Water, 1959-60, Underground water resources, parts R, S, and T: Ohio Dept. Natural Resources, Ohio Water Plan Inventory Maps.

_____ 1959, Water resources of southeastern Ohio: Ohio Dept. Natural Resources, 55 p.

Ohio Division of Water, 1961, Water inventory of the Mahoning and Grand River basins and adjacent areas in Ohio: Ohio Dept. Natural Resources, Ohio Water Plan Inventory Report No. 16, 90 p.

Piper, A.M., 1933, Ground water in southwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-1, 406 p.

Robison, T.M., 1964, Occurrence and availability of ground water in Ohio County, West Virginia: West Virginia Geol. and Econ. Survey Bull. 27, 57 p.

Smith, R.C., Doll, W.L., and Stratton, Garland, 1955, Water resources of the Wheeling-Steubenville area, West Virginia and Ohio: U.S. Geol. Survey Circ. 340, 31 p.

Van Tuyl, D.W., and Klein, N.H., 1951, Ground-water resources of Beaver County, Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W-9, 84 p.

MANAGEMENT CONSIDERATIONS

Use of ground water from the Ohio valley fill can be greatly increased with no undesirable consequences. In some parts of the valley the increase must be much less than in other parts, although the amount of increase warranted will not be known without careful study of specific locations. Despite the tremendous volume of permeable sediments comprising the Ohio valley fill and the large flows of the river available for recharge, problems of ground-water development do exist. In some stretches of the river, deposits of fine sediment, organic wastes, and industrial waste products on the channel bottom may have reduced the permeability of the river bed, and thus decreased the capacity for recharge of water from the river to the valley-fill sediments. Easing of this problem might be provided by the construction of off-channel recharge ponds which would be relatively easy to clean in contrast to the river bottom. The ponds could be maintained by diversions from the river that are filtered or otherwise treated as needed.

Screens in vertical wells tend to become encrusted thus causing reduced production and greater drawdowns in the wells. Yields from collectors are considerably greater than those of individual vertical wells, but costs per unit production would need to be calculated for each type of system to be considered for specific needs. The important consideration in water facilities tapping ground-water sources is that continued maintenance and replacement of equipment be included in the planning of facilities in much the same manner as in the use of construction or automotive equipment.

The potential for future development of the other major aquifers--the Mississippian sandstones, the Pottsville and Allegheny Formations, and the outwash in tributary valleys--is not so obvious nor has it been subjected to detailed study. Although the yield of these aquifers to individual wells is generally less than that of the Ohio valley fill, they extend over a larger area and thus the total development of water supplies from them could be significant. Because of the heterogeneous nature of these aquifers, future developments should be preceded by detailed hydrogeologic investigations.

Water-quality problems associated with waste-discharge and thermal loading in the Mahoning River indicate an increasing importance for ground-water development in the Beaver River basin. Many of the more economical surface-water supplies have already been developed and the cost of treating waste discharges to acceptable water-quality standards will increase. The use of ground water for alternate sources of supply, low-flow augmentation, reservoir replenishment, or other new uses seems inevitable.

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OHIO RIVER BASIN COMPREHENSIVE SURVEY. VOLUME VI. APPENDIX E. G--ETC(U)
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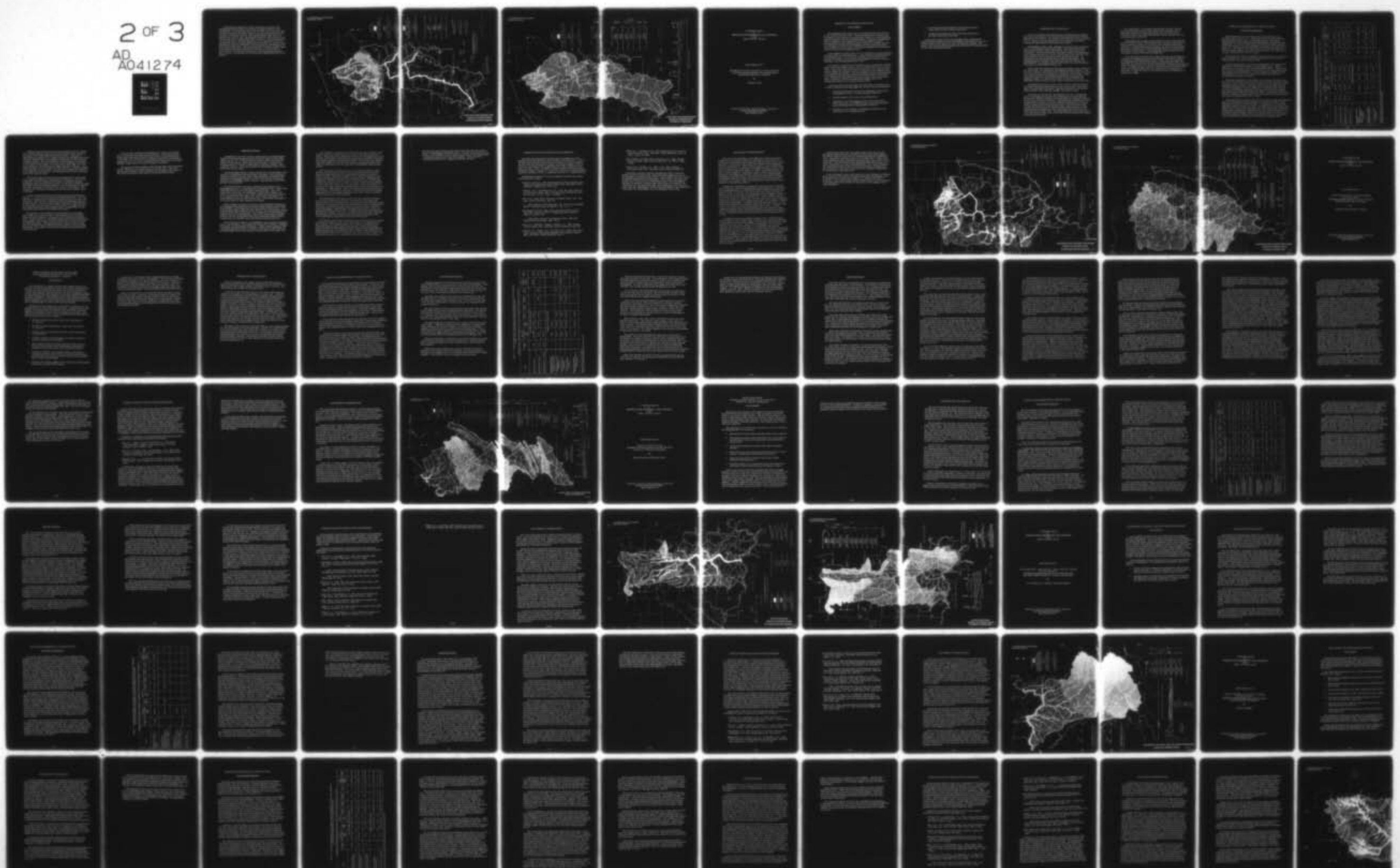

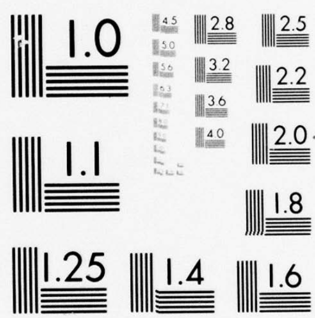
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In evaluating the potential for future development of ground water, consideration should be given to the effects of proposed surface-water developments. Increasing the level of surface water will increase the head in nearby confined or unconfined aquifers, and will increase the saturated thickness of unconfined aquifers, thus making possible higher yields of ground water at lower cost. The proposed Ohio River-Lake Erie waterway, following the Beaver and Mahoning Rivers to Warren, and connecting waterways to Lake Erie, would have these effects on the outwash in the Beaver and Mahoning valleys, although pooling the water might also cause increased deposition of silt on the streambed, thus decreasing the permeability of the bed to induced infiltration. The dams proposed to maintain navigable depths would increase the ground-water head by as much as 50 feet along the Beaver River, thus saturating much more of the unconsolidated material than at present, and perhaps even saturating some highly permeable terrace deposits.

U.S. DEPARTMENT OF THE INTERIOR
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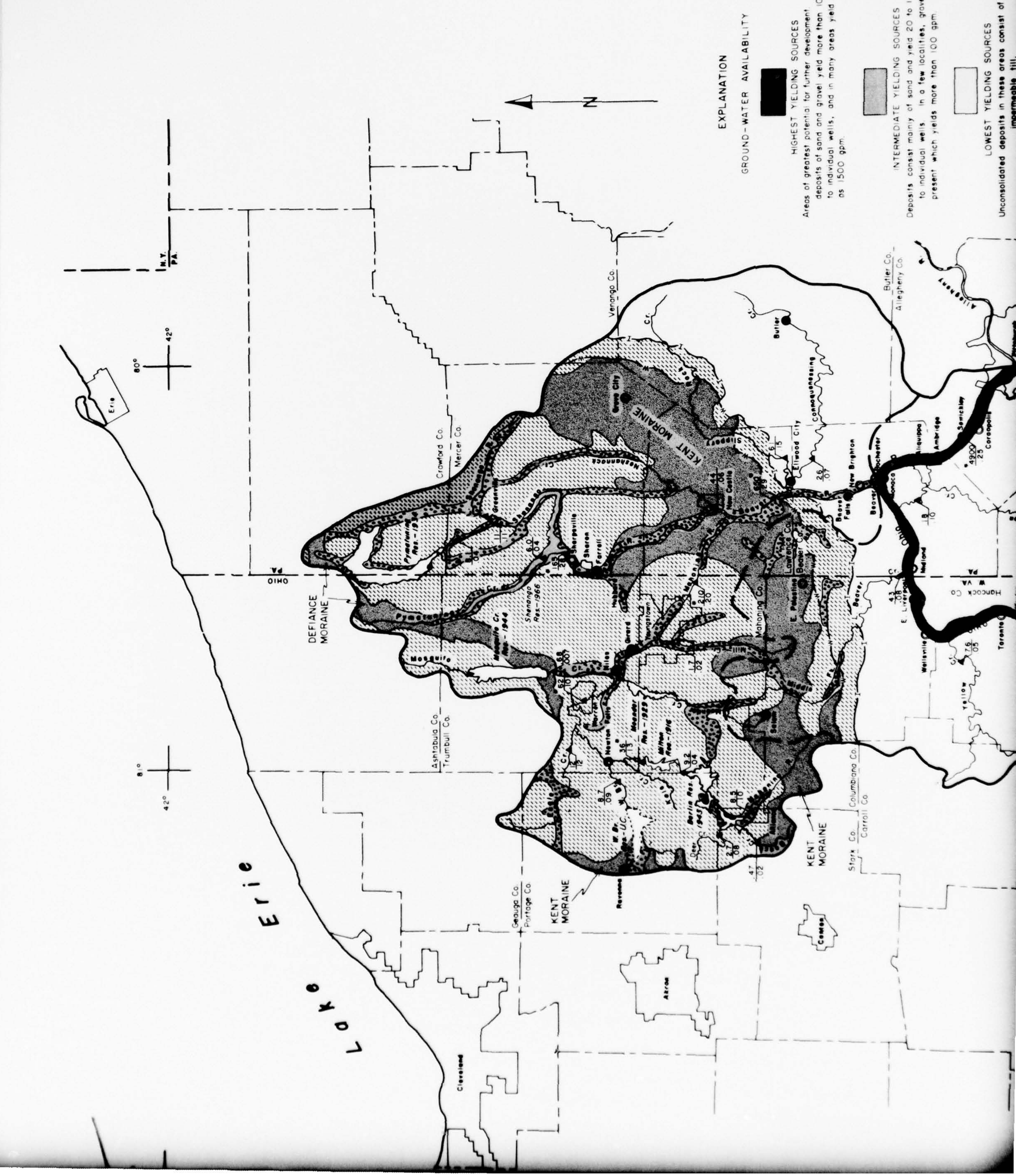
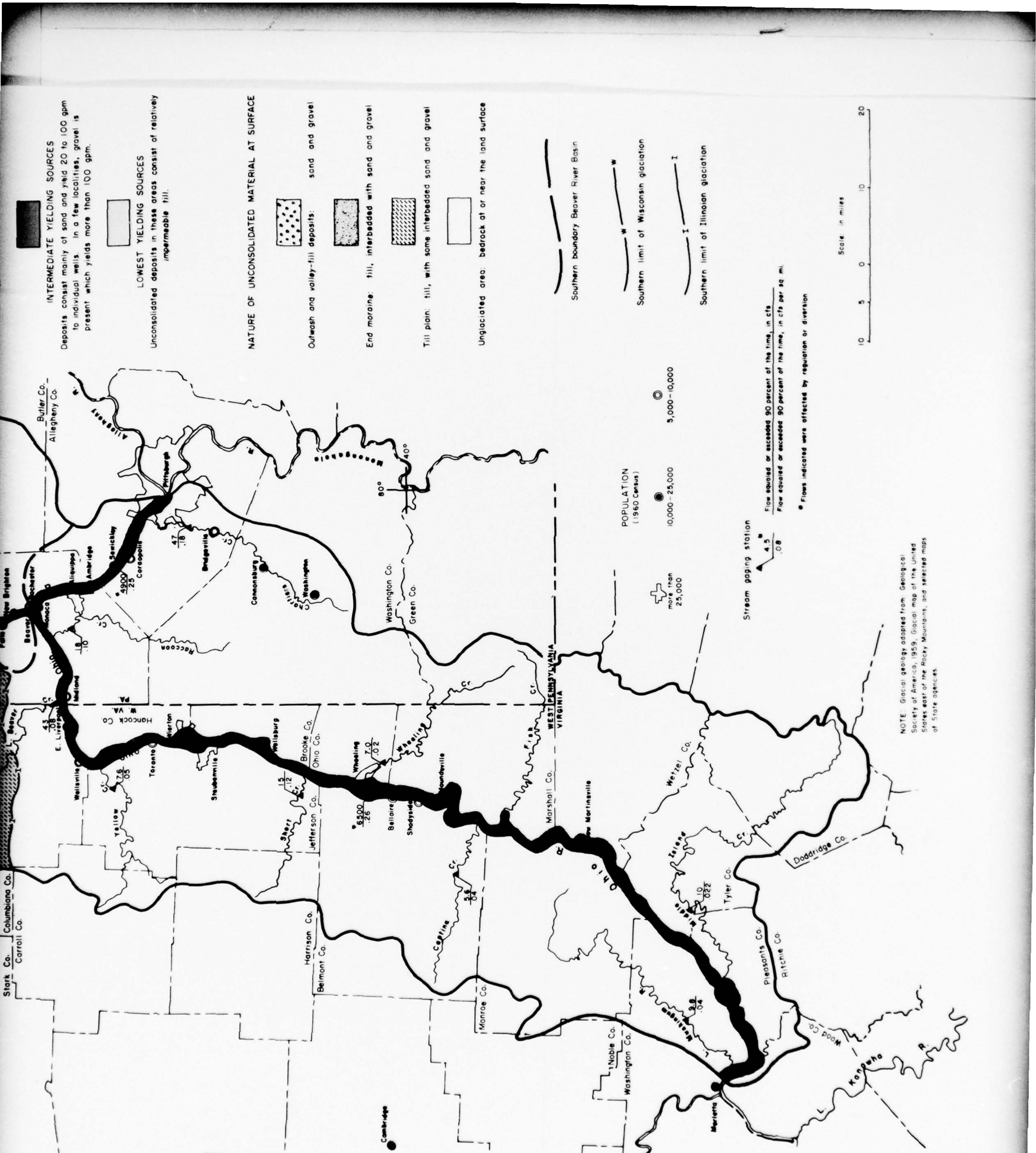
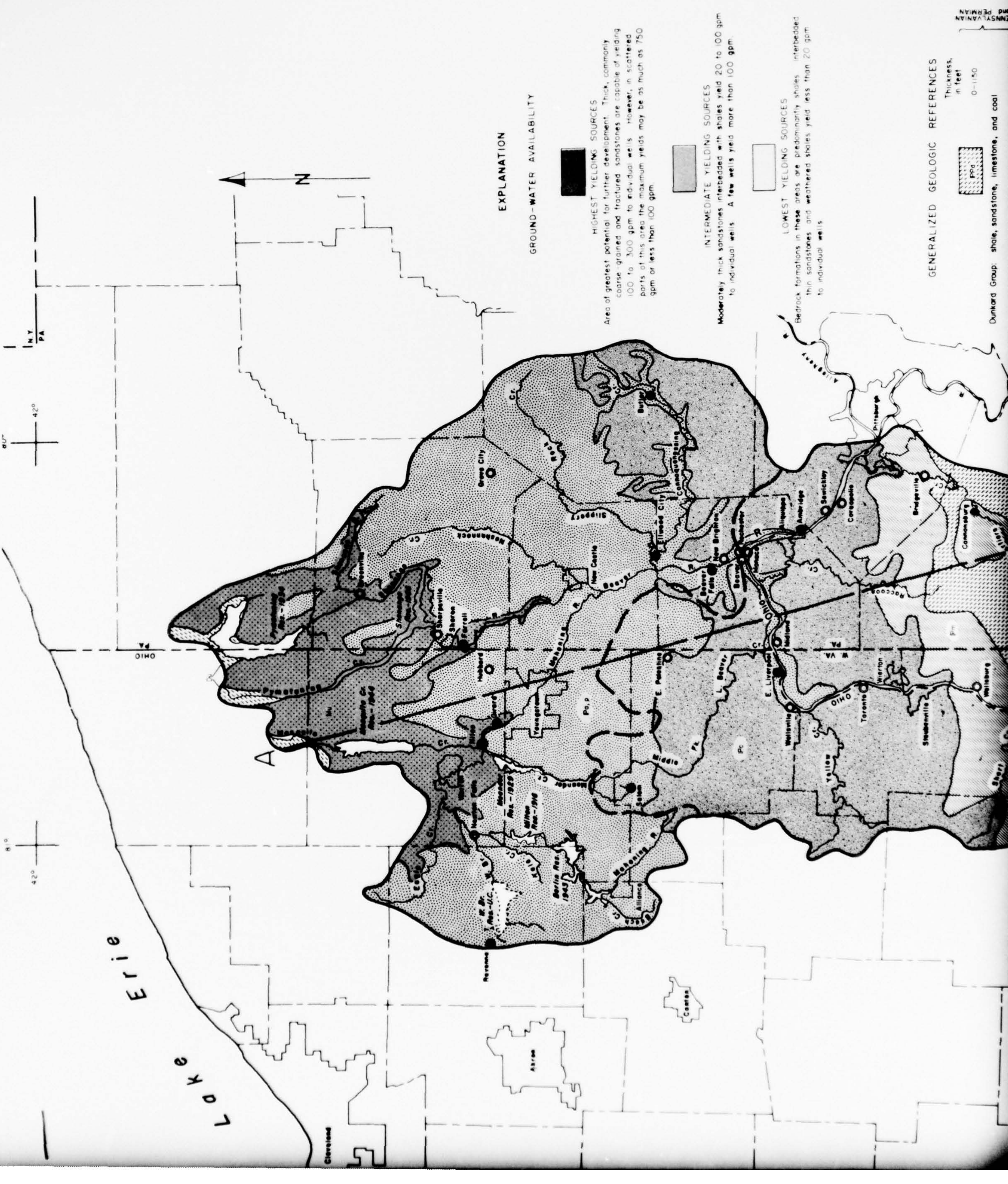


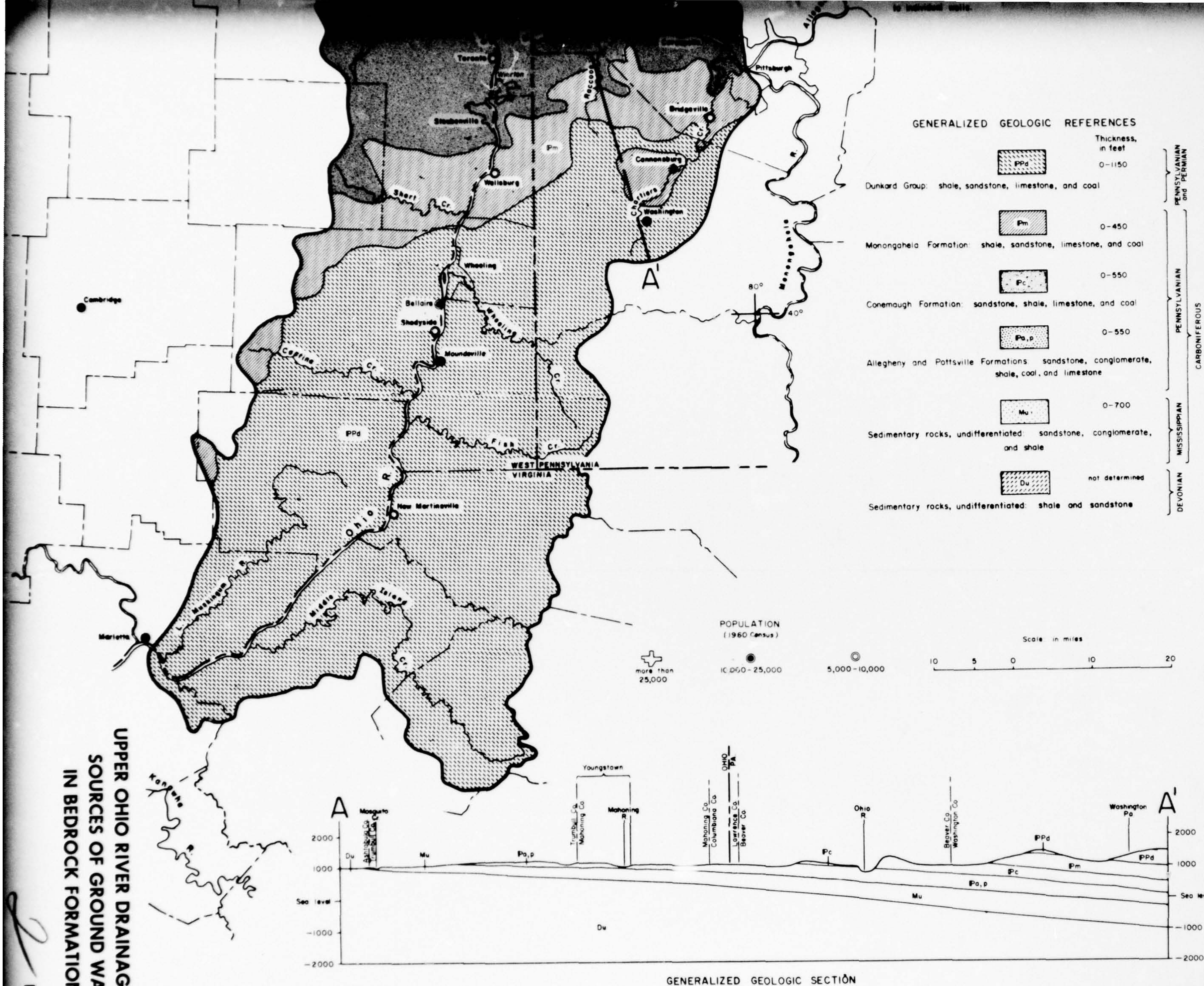


UPPER OHIO RIVER DRAINAGE AREA SOURCES OF GROUND WATER IN UNCONSOLIDATED SEDIMENTS

PLATE 9

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY





NOTE: Geologic base data adapted from selected maps of the U.S. Geological Survey and State agencies

UPPER OHIO RIVER DRAINAGE AREA SOURCES OF GROUND WATER IN BEDROCK FORMATIONS

PLATE 10

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 4

MUSKINGUM AND HOCKING RIVER BASINS
(Including northside drainage area to the Ohio River
between Marietta and Pt. Pleasant)

By

George D. Dove

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

MUSKINGUM AND HOCKING RIVER BASINS

CONCLUSIONS

The Muskingum River basin is one of the better ground-water regions in Ohio and the Ohio River basin. The greatest potential for ground-water development in the basin lies in the glaciated northern and western portions, especially along the courses of the Walhonding, Tuscarawas, and Muskingum Rivers. Individual wells drilled into the outwash deposits along the Walhonding River and its tributaries yield as much as 1,200 gpm; as much as 2,000 gpm is obtained from the deposits along the Tuscarawas River and its tributaries; and as much as 1,500 gpm is obtained from the deposits along the course of the Muskingum River.

Large supplies of ground water are also available from glacial sediments along the course of the Hocking River. In the glaciated northwestern portion of the Hocking basin, near Lancaster, individual wells yield more than 500 gpm, but south of Lancaster the outwash deposits are thinner and less permeable, and consequently yield less water.

The western, glaciated part of the report area is underlain by sandstone layers of the Mississippian System, which are important sources of ground water. In the central and eastern parts of the basin, away from the major stream valleys, the principal sources of ground water are sandstone strata of the Pennsylvanian System. Only small supplies of ground water generally are available in the unglaciated eastern and southern parts of the report area, where the bedrock formations consist largely of fine-grained sandstones, siltstones, and shales comprising the upper strata of the Pennsylvanian System and overlying Permian rocks.

In the area covered by this report, the chief sources of ground water, in order of estimated decreasing potential, and their general locations are:

1. Outwash deposits in the valleys of the Walhonding, Tuscarawas, and Muskingum Rivers, and their principal tributaries.

2. Outwash deposits in the valley of the Hocking River.

3. Sandstones of the Mississippian System in the western part of the report area, and especially where overlain by permeable glacial-drift deposits that readily permit recharge.

4. Sandstones of the Pottsville and Allegheny Formations in the central part of the Muskingum basin.

5. Unconsolidated glacial deposits in the buried pre-glacial Teays Valley between Trinway and Newark.

6. Sandstones and siltstones of the Conemaugh Formation in the east-central part of the basin.

Ground-water sources have been developed rather intensively for supply purposes at points of need in metropolitan and industrial areas, but in broad regions of the report area they are relatively untapped. The ground-water sources listed above generally yield water of a quality suitable for most uses with little treatment.

PHYSIOGRAPHY AND DRAINAGE

The area covered by this report includes the Muskingum and Hocking River basins and adjacent areas in Ohio drained by the Ohio River between Marietta and Pt. Pleasant. The alluvium of the Ohio River between Marietta and Pt. Pleasant is not included herein, but is reported in the section covering the Little Kanawha and Kanawha River basins.

The Muskingum basin, with a drainage area of more than 8,000 square miles, is the largest drainage basin in Ohio. The basin extends about 125 miles from north to south, and about 100 miles east to west at its widest point. The Tuscarawas River, headwater stream of the Muskingum, rises in glacial deposits near Akron, about 25 miles from Lake Erie, and flows southward west of Canton across the Appalachian Plateau. At Coshocton it joins the Walhonding River to form the Muskingum. The Walhonding River is formed at the confluence below Mt. Vernon of the Kokosing River and the Mohican River, which drains the northwestern part of the basin in the Mansfield-Ashland area.

Wills Creek flows northwestward through Cambridge in the southeastern part of the basin, and empties into the Muskingum below Coshocton. The last major tributary, the Licking River, drains the western part of the basin in the Newark area and discharges to the Muskingum at Zanesville. From Zanesville to Marietta, the Muskingum River flows through sparsely populated country in a rather narrow valley cut into the rocks of the Appalachian Plateau during the latter stages of glaciation in the Ohio Basin.

The Hocking River basin covers an area of about 1,180 square miles and except for its glaciated headwaters area near Lancaster, the basin is hilly with moderately steep slopes. Important tributaries to the Hocking River are Rush, Clear, Monday, Sunday, and Federal Creeks.

The great ice invasions into Ohio probably were the most important factors in changing the drainage and surface features in the Muskingum River basin. Glacial processes were responsible for changing the drainage of every major stream in the basin. Great quantities of glacial drift were deposited in the northern and western parts of the basin and in the major stream valleys many miles past the ice fronts. The Tuscarawas River occupies the old channel of the Massillon River (Stout and others, 1943), which gathered its headwaters south of Zanesville and flowed north past Akron into the Lake Erie basin. The Walhonding River follows the course of the old Warsaw Creek, which was greatly widened and filled with sediment during the glacial period.

The Licking River, which flows eastward from Newark, formerly followed the present course of Wills Creek to West Lafayette where it entered the Tuscarawas Valley and followed this valley westward to Conesville, where it left the present drainage channel and continued westward past Hanover to Newark.

The Hocking River occupies the pre-glacial channels of the Lancaster River and Stewart Creek. The Lancaster River rose near Haydenville and flowed northward, and Stewart Creek rose near Nelsonville and flowed southward. Ponded during the glacial period, the waters of the Lancaster River found an outlet near the Athens-Hocking County line and flowed into the Stewart Creek drainage. The drainage thus formed at this time was very similar to that of the present Hocking River.

The construction of sixteen flood-control reservoirs by the Corps of Engineers has significantly altered the hydrologic and surface features of the Muskingum and Hocking River basins. These reservoirs were built primarily for flood control on the Ohio River during the late 1930's, but some have been leased to the state for development as fishing and recreational areas. In addition to these reservoirs, other recreational facilities within the basins include Buckeye Lake, the Portage Lakes, and Clear Fork Reservoir, of which the latter is also used by the city of Mansfield for its public water supply.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

Glacial deposits cover the northern and western portions of the Muskingum River basin (pl. 11). These deposits are more than 300 feet thick in Ashland, Wayne, Knox, and Licking Counties, and in places completely obscure the underlying bedrock topography, producing a gently rolling plain. Toward the central part of the basin, the deposits become thinner and in places only scattered pebbles reveal the former extent of the glacial ice. The depth of wells drilled into the till deposits ranges from 30 feet in Summit County to 350 feet in Ashland County. The wells have an average sustained yield of less than 3 gpm.

The outwash sand and gravel deposits, called valley train, are the best aquifers in the basin. These deposits readily absorb water, store it in large quantities, and yield it freely to wells.

These permeable sands and gravels are deposited in the valleys of the Tuscarawas, Walhonding, Licking, and Muskingum Rivers. Similar deposits also are present in the valley of the Hocking River. These rivers, all of which have relatively high sustained flows, are fed by discharge from these glacial valley-fill deposits. As these deposits are tapped for future developments, the rivers will provide large and perennial sources of recharge to these important aquifers.

Municipal and industrial wells drilled in the valleys of the Tuscarawas River and its tributaries range from 69 to 175 feet in depth and are favorably situated to receive recharge from the overlying streams. Individual wells reportedly yield as much as 2,000 gpm, and one large-diameter collector at Canton is pumped at the rate of 3,500 gpm. Use of the water from the sand and gravel deposits undoubtedly will require treatment for hardness, which ranges from about 150 to 400 mg/l (table 4), and averages more than 250 mg/l. Dissolved solids content of the water ranges from 195 to 640 mg/l. Iron content is generally less than 0.5 mg/l.

Wells drilled into the glacial outwash sand and gravel along the Walhonding River and its tributaries range in depth from about 35 to 300 feet. Many individual wells yield more than 500 gpm. A municipal well at Coshocton reportedly yields more than 2,000 gpm. All of the water sampled from these deposits was hard, ranging from about 150 to 360 mg/l and had a dissolved solids content ranging from about 190 to 450 mg/l. With the exception of the municipal well at Coshocton, which had an iron content of 0.2 mg/l, all of the water sampled was higher in iron content than 0.3 mg/l, the maximum limit recommended by the Public Health Service for drinking water.

TABLE 4.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE MUSKINGUM AND HOCKING RIVER BASINS.[a]

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (°F)
		Unconsolidated Sediments[b]							
Tuscarawas River valley	20-150	100-2000	40-290	150-470	---	2-130	0.2-4.0	200-650	51
Walhonding River valley	20-100	180-2100	35-180	150-320	---	2-30	0.1-2.0	180-450	51
Muskingum River valley	20-150	100-1000	40-230	250-900	---	0-800	0.0-8.0	330-1000	52
Hocking River valley	15-75	75-500	45-140	250-410	---	2-35	0.1-2.4	300-560	52
		Bedrock Formations							
Mississippian System, undivided: Logan, Cuyahoga, and Berea Formations (sandstones)	---	100-600	20-430	30-570	---	0-140	0.1-3.0	50-1000	52-58
Allegheny and Pottsville Formations (sandstone)	---	50-500	35-500	20-520	---	0-650	0.3-5.0	200-1000	52-58
Conemaugh Formation (sandstone)	---	5-40	35-365	40-160	---	5-200	0.3-3.0	250-1000	52-57

[a] Including adjacent areas draining to the Ohio River from the north between Marietta and Pt. Pleasant.
[b] Based on municipal and industrial pumpage.

Individual wells drilled into the valley-fill deposits along the Licking River and its tributaries typically do not yield as much water as those in the valleys of the Walhonding and Tuscarawas Rivers. This may be explained by the presence in the Licking valley of two widespread clay layers within the valley fill that act as barriers to infiltration of water from the overlying streams. Wells drilled into the outwash deposits range from 30 to more than 300 feet in depth, and yield as much as 600 gpm. All of the water sampled was extremely hard, ranging from 280 to 420 mg/l. The dissolved mineral content ranged from 380 to 630 mg/l. With the exception of the municipal well at Granville, all of the water samples were reported to have high iron concentrations. The municipal well at Hebron reportedly had an iron content of 8 mg/l.

The outwash sands and gravels in the Muskingum River valley range from a maximum thickness of about 140 feet at Coshocton to about 70 feet at Marietta. Between Coshocton and Dresden, the deposits along the Muskingum River reportedly yield as much as 1,500 gpm to individual wells, and south of Dresden, individual yields of as much as 500 gpm are reported. The water has only small amounts of iron, but is extremely hard. The municipal well at Philo had a hardness of 900 mg/l and a chloride content of 800 mg/l.

A part of the abandoned channel of the pre-glacial Cambridge River (Stout et. al., 1943, p. 65) lies between Trinway and Hanover. This old channel is as much as 300 feet deep and is filled with layers of clay, sand, and gravel. Little data are available concerning the hydraulic character of these deposits. Because of the presence of numerous alternating layers of silt and clay, and the absence of a surface stream to supply recharge, the sustained yields from these deposits would be considerably less than from those in the valleys of the present-day streams.

The thickest and most permeable outwash deposits in the Hocking River valley occur near Lancaster. These deposits range from 120 to nearly 200 feet in thickness, and yield as much as 500 gpm to individual wells. South of Lancaster, the deposits become thinner and less permeable. The municipal wells at Logan are about 60 feet deep, and those at Athens are about 50 feet deep. Throughout the valley, however, fine sand and poorly sorted gravel layers limit the sustained yield of wells by clogging well screens, thus making it necessary to frequently redevelop the wells, or drill new ones.

All of the water sampled in the Hocking River valley was extremely hard, and for most uses would require treatment. The hardness of the water ranged from about 250 mg/l at Sugar Grove to more than 400 mg/l at Chauncey. Iron was present in all samples collected in concentrations ranging from 0.1 to 2.4 mg/l. Dissolved solids ranged from a low of about 300 mg/l at Sugar Grove to a high of 560 mg/l at Chauncey.

The glacial and alluvial deposits along the Ohio River between Marietta and Pt. Pleasant are an excellent source of ground water. The water-bearing characteristics of these sediments are described in the section of this report covering the Little Kanawha and Kanawha River basins.

Bedrock Formations

Consolidated rocks of the Permian, Pennsylvanian, and Mississippian Systems are extensively exposed in the central and southern parts of the report area (pl. 12). In the northern and western areas, the bedrock formations are covered by a thick mantle of glacial drift. Included in the bedrock systems are strata of conglomerate, sandstone, siltstone, shale, limestone, and coal. Rocks lying beneath the Mississippian System do not yield water of good quality.

The Mississippian System in Ohio is divided into six stratigraphic units. These are in descending order the Maxville Limestone, Logan Formation, Cuyahoga Formation, Sunbury Shale, Berea Sandstone, and Bedford Shale. Rocks of the Mississippian System are about 700 to 800 feet in aggregate thickness in the Muskingum basin, and have a regional dip of 25 to 40 feet per mile to the southeast.

In the western part of the basin, sandstones and siltstones of the Mississippian System are the predominant consolidated rocks. These rocks reportedly yield as much as 600 gpm to individual wells. In the west-central part of the basin, near Mansfield, Jeromesville, Danville, and Utica, the more productive wells range in depth from about 200 to 300 feet. In the southern part of the report area, near Amanda and Rushville, the more productive wells are about 100 feet deep. The Maxville Limestone is not a known source of water anywhere in the basin.

Water samples collected from wells in the Mississippian sandstones in the Muskingum basin generally are of good quality, except for the presence of undesirable concentrations of iron at some locations (see table 4). The wells sampled range in depth from 60 to 460 feet, and average about 180 feet. Hardness of the water ranged from a low of about 20 mg/l at Rockbridge to a high of 570 mg/l at Marshallville. Most of the water sampled contained less than 500 mg/l of dissolved solids, but the dissolved solids content of a sample from an industrial well at Marshallville exceeded 900 mg/l.

The Pennsylvanian System in the Muskingum basin consists of sandstone, shale, coal, limestone, and conglomerate strata of the Pottsville, Allegheny, Conemaugh, and Monongahela Formations. Rocks of these formations have a maximum thickness of about 1,000 feet and overlie the eroded surface of the Mississippian rocks in the central and eastern parts of the report area.

The Pottsville and Allegheny Formations are the most productive rocks of the Pennsylvanian System, yielding as much as 600 gpm to wells near Canton. The wells range in depth from about 90 feet near Kimbolton to about 430 feet at Shanesville. Water from these formations generally is very hard and contains undesirable concentrations of iron. Most of the water samples from wells tapping the Pottsville and Allegheny Formations had dissolved solids concentrations of less than 500 mg/l, and negligible chloride concentrations.

The Conemaugh Formation, which has a maximum thickness of about 380 feet, crops out in the northeast and south-central parts of the basin. Most of the wells drilled into the Conemaugh Formation average about 120 feet in depth. The largest supplies of water from the formation, 20 to 40 gpm, are obtained in the vicinity of Guernsey County. Throughout the remainder of the basin, yields average about 5 gpm, but it is not recorded whether these yields represent aquifer capability, limited domestic demand, or well-construction deficiencies. Because of the large concentrations of iron, 0.3 to 3.2 mg/l, treatment probably will be necessary before the water is suitable for most purposes. The water commonly has a hardness of less than 100 mg/l. The village of Byesville, in Guernsey County, has recently supplemented its water supply by pumping water from a nearby abandoned coal mine in the Conemaugh Formation.

The Monongahela Formation near the top of the Pennsylvanian System has a maximum thickness of 260 feet, and crops out in the central and southern parts of the Muskingum basin and in Meigs County north of Pomeroy. There are no large towns or industries obtaining water from the Monongahela Formation, and consequently its maximum yield is not known. However, the average depth of wells drilled into the formation is about 75 feet, and yields generally are 3 gpm or less. In addition, numerous well failures and dry holes are reported. Salt water is encountered in many wells more than 200 feet deep, and in the southern part of the basin near Pomeroy, salt water reportedly is encountered in wells about 70 feet deep.

The Dunkard Group of the Pennsylvanian and Permian System is exposed at the surface along the southern part of the report area from Marietta to near Pomeroy. The Dunkard Group, which consists of sandstones that grade laterally into shales within short distances, attains its maximum thickness of 470 feet in Washington County. Depths of wells drilled into the Dunkard Group range from about 40 to 230 feet and average about 100 feet. Wells drilled into the massive sandstones may yield as much as 5 gpm. The average yield, however, is 2 gpm or less and numerous well failures and

dry holes have been reported in the Duck Creek basin and in the southern parts of the Muskingum and Hocking basins. Because of the numerous well failures, many property owners in upland areas along the Ohio River depend on cisterns or dug wells for their water supplies. Also many wells reportedly yield salt water at depths greater than 100 feet.

CURRENT STATUS OF GROUND-WATER INFORMATION

Reconnaissance-type maps on ground-water availability have been published by the Ohio Division of Water (1958) for the entire state. A more detailed report covering the ground-water resources in various localities, and which includes information on present and former drainage courses of streams for the entire state, was published by the Ohio Geological Survey (Stout and others, 1943). In addition, detailed reports on the ground-water geology of Fairfield, Licking, and Tuscarawas Counties have been published by the Ohio Division of Water in cooperation with the U.S. Geological Survey.

Bibliographic citations for the more significant ground-water reports in the basin are as follows:

Cummins, James W., 1947, Reconnaissance survey of ground-water resources in southwestern Stark County, Ohio: Ohio Dept. Natural Resources, unpubl. rept., UP-1, 3 p.

Cummins, J.W., and Sanderson, E.E., 1947, The water resources of Tuscarawas County, Ohio: Ohio Dept. Natural Resources, Geol. Survey, Bull. 6, 52 p., 18 pls., 30 tables.

Dove, G.D., 1960, Water resources of Licking County, Ohio: Ohio Dept. Natural Resources, Bull. 36.

_____ 1960, Drainage of the Teays Stage, Mt. Vernon and Cambridge Rivers: The Ohio Journal of Science, v. 60, no. 2.

Ohio Division of Water, 1958, Ohio water plan inventory project: Ohio Dept. Natural Resources, Underground water resources maps O 1-4 and P 1-19.

_____ 1959, Water resources of southeastern Ohio: Ohio Dept. Natural Resources prelim. rept., 55 p.

Root, S.F., Rodriguez, Joaquim, Forsyth, J.L., 1961, Geology of Knox County, Ohio: Ohio Dept. Natural Resources, Bull. 59.

Schaefer, E.J., White, G.W., Van Tuyl, D.W., 1946, The ground-water resources of the glacial deposits in the vicinity of Canton, Ohio: Ohio Dept. Natural Resources, Bull. 3.

Smith, R.C., and White, G.W., 1953, The ground-water resources of Summit County, Ohio: Ohio Dept. Natural Resources, Bull. 27, 130 p., 22 pls., 6 tables.

Stout, Wilber, Ver Steeg, Karl, and Lamb, G.F., 1943, Geology of water in Ohio: Geol. Survey of Ohio, Bull. 44, 694 p., 8 figs., 1 table.

Wolfe, E.W., Forsyth, J.L., Dove, G.D., 1962, Geology of Fairfield County, Ohio: Ohio Dept. Natural Resources Bull. 60.

Information currently available, including this report, shows that prolific sources of ground water are present within significant areas of the Muskingum and Hocking River basins. These reports, however, contain insufficient hydrogeologic and geochemical data for those areas where the ground-water resource may be extensively used for future development. Detailed investigations to provide these types of data are needed for the following areas: the Walhonding basin, the Licking basin, the Tuscarawas basin above New Philadelphia, and the valley-fill deposits in the Tuscarawas valley below New Philadelphia and in the Muskingum River valley.

MANAGEMENT CONSIDERATIONS

This study of the Muskingum and Hocking River basins reveals that ground water in quantities adequate for municipal and industrial uses is available from the glacial outwash deposits along the major stream valleys. The water is generally of good quality and is suitable for most purposes without costly treatment. These aquifers extend for more than 200 miles along the Tuscarawas, Walhonding, and Muskingum Rivers, and for lesser distances along the Kokosing, Mohican, Licking, and Hocking Rivers, and Sugar, Sandy, Chippewa, and Killbuck Creeks. Although the hydrologic properties of the aquifers of the basin are not known in sufficient detail for planning of specific projects, the volume of ground water in storage is undoubtedly many times greater than the volume of water in the surface reservoirs in the basins. Hence, the ground-water resource offers great potential in basinwide management.

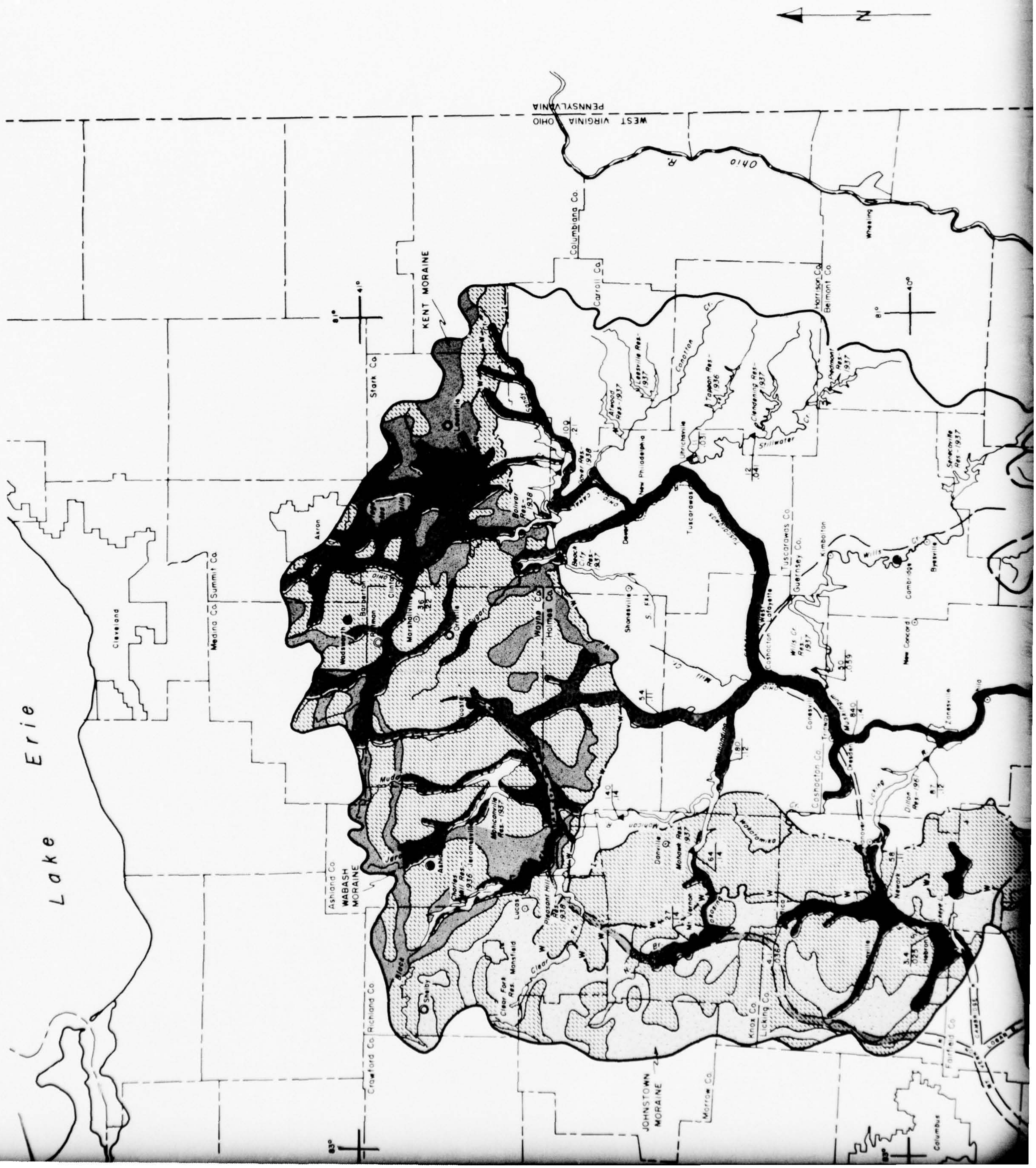
Despite the availability for development of ground water from glacial outwash deposits, water-quality problems may be encountered. One of the major quality problems is in northeastern Wayne County and southwestern Summit County. In this area salt is mined from the Salina Formation of Silurian age and some of this salt undoubtedly gets into Chippewa Creek and the old Ohio Canal which flow through the area. Water samples taken on the Tuscarawas River at Clinton for chemical analysis show that the chloride content of the river has been as high as 6,600 mg/l, and as high as 3,600 mg/l downstream at Massillon. A detailed study of the hydraulic regimen of the valley-fill deposits will be required to determine the effects on quality of the ground water caused by induced infiltration of river water. A water-management program that includes development of this important aquifer would be concerned with the abatement of chloride discharge to the streams, means of avoiding recharge of contaminated water to streamside aquifers, or both.

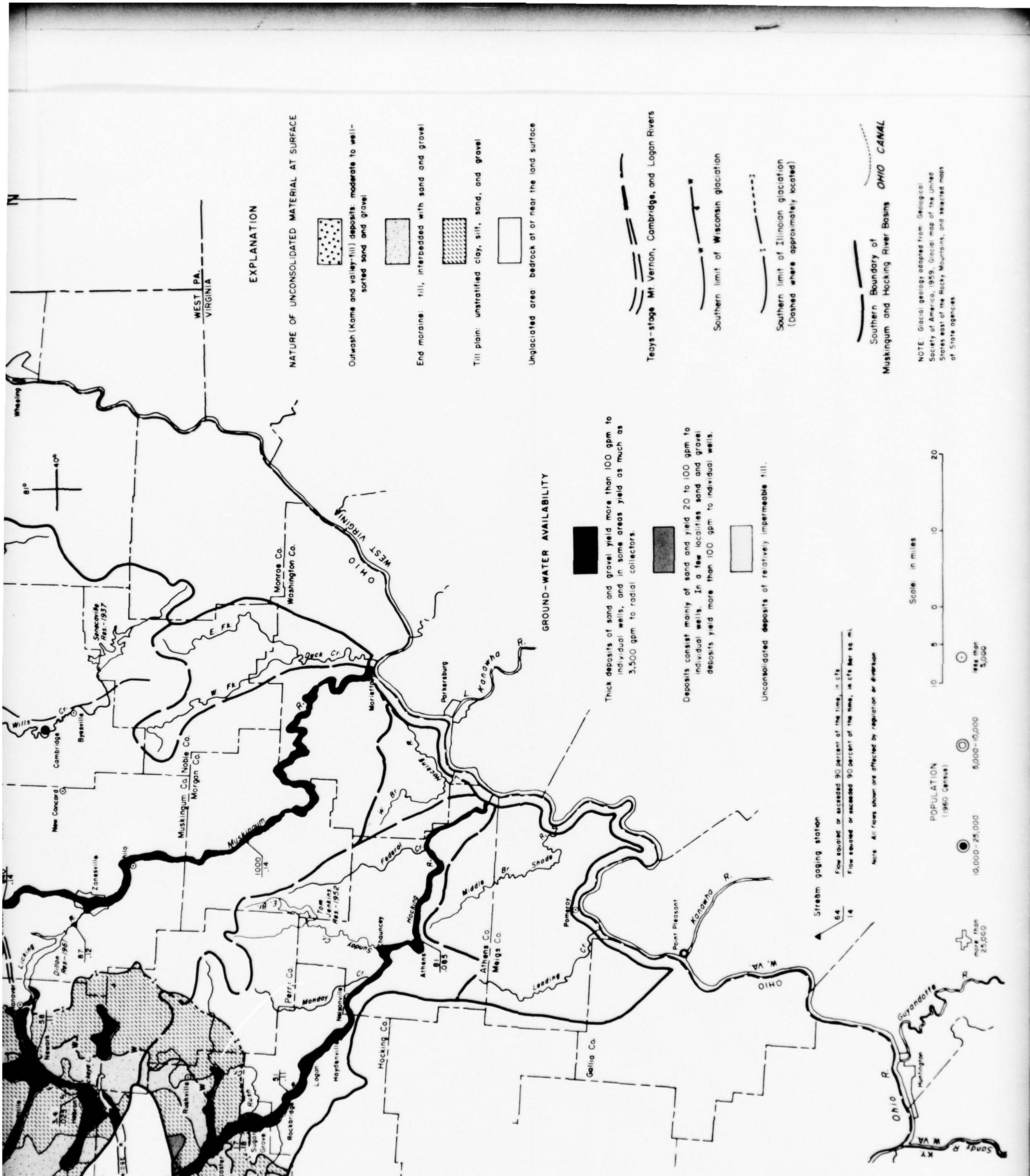
In addition to the large quantities of ground water available from the outwash deposits in the stream valleys, there is also considerable potential for development from the Mississippian and Pennsylvanian sandstones in the northern part of the basin. South of New Philadelphia, yields from the Pottsville and Allegheny Formations are considerably more limited. Although they are not as permeable nor as readily rechargable as the outwash deposits along the rivers, consolidated bedrock aquifers locally have provided fairly large supplies of water at a number of places within the Muskingum basin as described above. Presently available data, however, are not sufficiently detailed to accurately delineate large-yield areas within the bedrock formations. Since ground-water supplies are generally obtained at the point of need, reported yields do not necessarily represent maximum yields from the aquifer.

A large area in the eastern and southern parts of the basin has the development potential for only moderate to small ground-water supplies. The surface streams in this area are underlain by relatively impermeable rocks. The streams therefore have low dry-weather flows. Large-scale water development would undoubtedly necessitate the construction of surface reservoirs. The hilly terrain of the unglaciated Appalachian Plateau, the scenic countryside, and rather sparse population, have already resulted in the construction of flood-control and recreation projects, although many sites favorable for this type of use have not been developed, especially in the southern part of the report area.

If the full potential of the water resources of the Muskingum and Hocking River basins is to be realized, systematic exploration, development, and management of the ground-water aquifers on a regional basis will be necessary. Long-range planning should consider the great reserve potential of the underground water resource to solve future water-supply or water-quality problems.

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



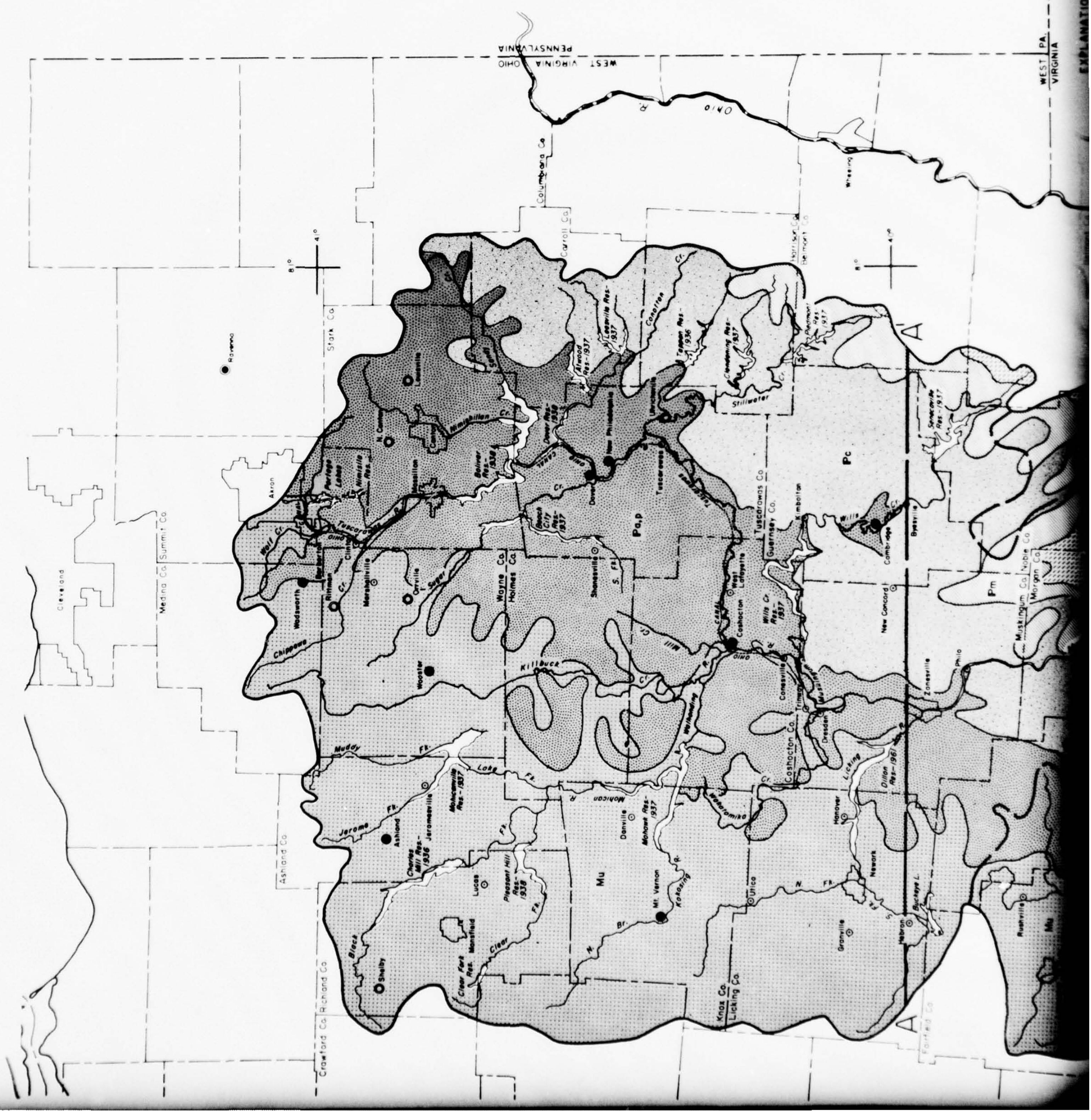


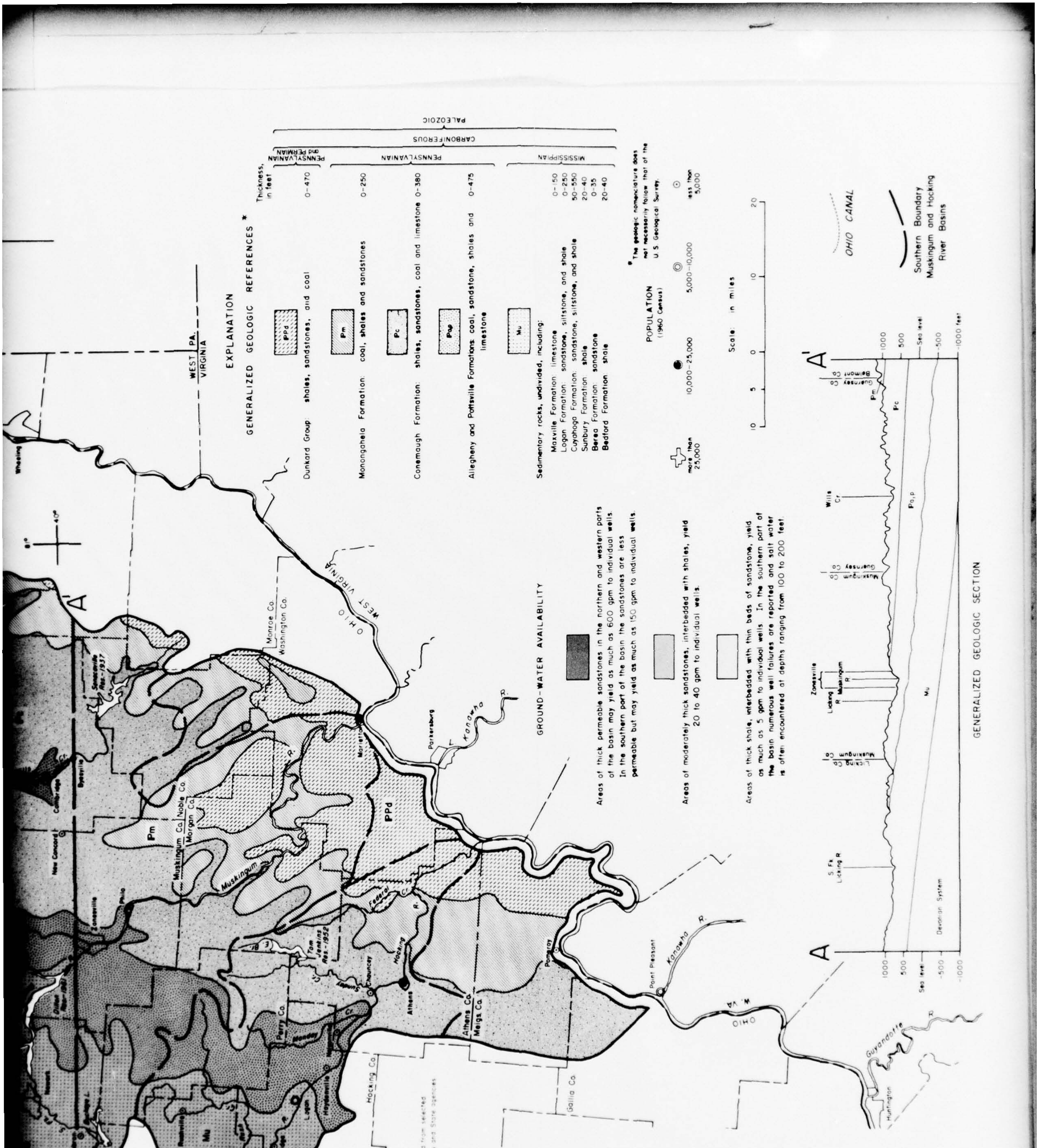
MUSKINGUM AND HOCKING RIVER BASINS
SOURCES OF GROUND WATER
IN UNCONSOLIDATED SEDIMENTS

2

PLATE 11

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY





MUSKINGUM AND HOCKING RIVER BASINS
SOURCES OF GROUND WATER
IN BEDROCK FORMATIONS

PLATE 12

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 5

LITTLE KANAWHA AND KANAWHA
RIVER BASINS
(Including southside drainage area to the Ohio River
between Marietta and Pt. Pleasant)

By

George D. Dove and Joe C. Wallace

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

LITTLE KANAWHA AND KANAWHA RIVER BASINS
(Including southside drainage area to the Ohio River
between Marietta and Pt. Pleasant)

CONCLUSIONS

The availability of an adequate ground-water supply from the river alluvium is one of the principal reasons for the location of industry in the valleys of the lower Little Kanawha, Ohio, and lower Kanawha Rivers. Ground-water supplies from these deposits are not only adequate to meet existing industrial and public demands, but also offer considerable potential for future development. Wells drilled into the alluvial deposits along the Ohio River yield up to 1,500 gallons per minute, and wells drilled into the alluvial deposits along the lower reaches of the Little Kanawha and Kanawha Rivers reportedly yield as much as 100 gallons per minute.

Consolidated rocks ranging from Precambrian to Permian in age are exposed at the land surface throughout the basins. Adequate ground-water supplies for domestic needs are available from these rocks, and larger supplies for industrial or public use are available in some areas. The chief sources of ground water, in order of estimated decreasing potential, and their general locations are as follows:

1. Alluvium along the Ohio River valley from Parkersburg to Pt. Pleasant.

2. Alluvium along the Kanawha River valley from Charleston to Pt. Pleasant.

3. Alluvium along the Little Kanawha River valley from Elizabeth to Parkersburg.

4. Sandstone aquifers of the Pottsville and Allegheny Formations in central and eastern West Virginia.

5. Metamorphosed gneiss and schist along the course of the New River in North Carolina and the metamorphosed phyllite and conglomerate along the course of the New River in Virginia.

6. Limestone, dolomite, and sandstone aquifers of Ordovician age along the course of the New River in southwestern Virginia, and limestone of Devonian age along the course of the Greenbrier River in eastern West Virginia.

7. Sandstone and siltstone aquifers of the Conemaugh and Monongahela Formations in western West Virginia.

Ground water in the basins in West Virginia generally is not highly mineralized and may be used for most purposes. The water from Pottsville and Allegheny sandstones, at depths of less than 300 feet, is suitable for domestic and industrial purposes with little or no treatment. However, in the vicinities of Burning Springs in the Little Kanawha River basin, and Charleston in the Kanawha River basin, geologic folding and uplift of the rocks has brought the deeper, more mineralized water close to the surface.

There is very little data available on the chemical quality of ground water from the gneiss, limestone, and dolomite aquifers in Virginia and North Carolina, but chemical analyses of surface waters in these areas show that the ground water may be fairly hard. In like manner, analyses of surface water from areas where phyllites and conglomerates are the principal aquifers indicate that the ground water from these rocks may be only slightly mineralized.

PHYSIOGRAPHY AND DRAINAGE

The area discussed in this report covers the Little Kanawha River basin, Kanawha River basin, and the remainder of the area draining to the Ohio River in West Virginia between Parkersburg and Pt. Pleasant. The total drainage area is about 15,150 square miles.

In this part of the Ohio River basin are four distinct types of physiography that are significant in the distribution of ground water. The headwaters area of the Kanawha basin lies in the rugged Blue Ridge Mountains of western North Carolina where fractured and jointed metamorphosed Precambrian rocks predominate. In the Valley and Ridge Province of Virginia and southern West Virginia, the Paleozoic sedimentary rocks are folded and faulted, resulting in a highly complex ground-water distribution pattern. Most of the area of the Kanawha and Little Kanawha basins lies within the Appalachian Plateau Province, where the sedimentary rock strata are essentially flat-lying, but the streams are deeply eroded into the rocks creating considerable topographic relief. In the plateau, broad areas are underlain by the same sequence of rock strata. Hence, hydrologic characteristics tend to be relatively uniform over broad areas. The valleys in the lower reaches of the Kanawha and Little Kanawha Rivers and the reach of the Ohio River lying within the area covered are filled with water-saturated alluvium, and the terrain is rather level.

The ground-water resources of the basin differ not only with physiography but also with changes in rock characteristics. Further, in a humid climate such as that in the basins under study, the rock type is the principal factor controlling the dry-weather flow of streams. For example, those streams having the highest dry-weather flow are in areas underlain by permeable alluvial deposits, sandstone, and limestone; and those streams with the lowest dry-weather flow are in areas underlain by relatively impermeable shale and siltstone (pl. 13).

SOURCES AND DISTRIBUTION OF GROUND WATER

The Little Kanawha River has its headwaters in the Pottsville Formation of Pennsylvanian age near Kanawha Head, West Virginia. From here, the river flows northwestward over progressively younger rocks to its junction with the Ohio River at Parkersburg. Except for the Burning Springs anticline, near the middle of the basin, the rocks are relatively flat-lying. These rocks consist of conglomerate, sandstone, and limestone, which are very good aquifers; and shale, clay, and coal, which are poor aquifers. In addition, extensive deposits of unconsolidated river alluvium occur along the lower reaches of the river between Elizabeth and Parkersburg and these unconsolidated deposits are the best sources of ground water in the basin.

The Ohio River of West Virginia, as included in this report, extends from the mouth of the Little Kanawha River at Parkersburg south to the mouth of the Kanawha River at Pt. Pleasant. The river alluvium offers the greatest potential for the development of ground water. These deposits are favorably situated to receive recharge from the river, and may also contribute water to the river during low-flow periods.

The consolidated rocks beneath the river alluvium and in the remainder of the drainage area consist of Dunkard shales from Parkersburg to Millwood, and Monongahela shales and sandstones from Millwood to Pt. Pleasant. These rocks receive little or no recharge from the river during high-flow periods, and contribute little or no water to the river during periods of low flow.

The Kanawha River is formed by the confluence of the New River and Gauley River at Gauley Bridge, West Virginia. The headwaters area of the New River is in the Precambrian rocks of the Blue Ridge Mountains of western North Carolina. The river flows northeastward into Virginia where it swings northwestward near Radford and cuts across the younger, Paleozoic rocks of the Valley and Ridge Province. As the river flows into West Virginia east of Princeton, it enters the Appalachian Plateau Province and is deeply entrenched into the Mississippian and Pennsylvanian rock strata downstream to near Charleston. From Charleston to its junction with the Ohio River at Pt. Pleasant, the Kanawha flows over a flood plain underlain by Recent river alluvium. The principal tributaries, the Greenbrier and Gauley Rivers, flow southwestward across Mississippian and Pennsylvanian rocks, respectively, and are entirely within West Virginia.

Unconsolidated Sediments

Extensive deposits of river alluvium occur along the lower part of the Little Kanawha River and its tributaries downstream from Elizabeth. These deposits are favorably situated to receive recharge from the river and probably offer the largest undeveloped source of ground water in the Little Kanawha basin. The alluvium, which contains beds of sand and gravel, is as much as 50 feet thick between Elizabeth and Parkersburg.

Municipal wells drilled into the alluvium at Elizabeth yield more than 100 gpm (table 5). A chemical analysis of water in the alluvium showed the water to be slightly acidic with a pH of 6.6. The water was soft, with a total hardness of only 42 mg/l, and also showed a low dissolved solids content of 110 mg/l.

The most important source of ground water in the entire area covered by this report are the alluvial deposits along the Ohio River. The deposits along the West Virginia side of the Ohio are as much as 2½ miles wide at Pt. Pleasant, and in some places are over 100 feet thick. In some places the river flows along bedrock cliffs, but where alluvial deposits are present they are commonly more than ½ mile wide.

The alluvial deposits at Parkersburg are about 3/4 mile wide and up to 55 feet thick. Parkersburg obtains its water supply from large diameter radial collectors dug into these deposits. Each collector is reported capable of yielding as much as 2 mgd (million gallons per day). North of Parkersburg, the alluvial deposits are as much as 100 feet thick. Vienna obtains its water supply from wells drilled into these deposits. The wells are about 100 feet deep and reportedly yield more than 200 gpm each.

South of Parkersburg, at Washington, the alluvial deposits are as much as 90 feet thick and contain 77 feet of sand and gravel. A large chemical plant at Washington pumps more than 2 mgd from one radial collector in these deposits.

There are no large withdrawals of ground water from the alluvial deposits from Washington south to Ravenswood. Ravenswood obtains its municipal water supply from two wells drilled about 20 feet into the alluvial deposits. Each of these wells has a capacity of about 250 gpm.

TABLE 5.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE LITTLE KANAWHA AND KANAWHA RIVER BASINS

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (°F)
		Unconsolidated Sediments							
Ohio River alluvium	10-60	200-1500[a]	55-100	130-300	---	---	---	220-460	52-58
Kanawha River alluvium	10-30	25-150	50-130	20-650	---	5-380	2-50	---	53-60
Little Kanawha River alluvium	10-20	10-100+	---	---	---	---	---	---	53-60
		Bedrock Formations[b]							
Pennsylvanian System: Monongahela Formation (sandstone and shale)	---	10-50	40-60	---	---	---	---	---	53-58
Conemaugh Formation (sandstone)	---	10-60	25-250	6-380	---	---	0-15	---	53-55
Allegheny Formation (sandstone)	---	120-600	40-300	10-190	---	3.0-1000	0.1-7.0	120-1000	53-56
Pottsville Formation (sandstone)	---	200-500	25-350	20-930	---	1.5-1000	0.0-38	---	53-56
Mississippian System: (undifferentiated sandstone and limestone)	---	20-400	80-600	80-290	---	---	---	42-530	---

[a]Large diameter radial collector
[b]Based on available information from West Virginia

Between Ravenswood and New Haven, the alluvial deposits are about a mile wide and almost 70 feet thick. Test drilling by a local industry showed that these deposits at New Haven contain as much as 50 feet of permeable sand and gravel, and thus offer great potential for future ground-water development. New Haven obtains its water supply from three wells in the alluvium, and a nearby industry pumps 330 gpm from one well.

At Pt. Pleasant, the alluvial deposits are more than 2½ miles wide, and average more than 65 feet thick. The West Virginia Ordnance Works, which was operated by the Corps of Engineers during World War II, used six radial collectors that tapped these deposits.

Water in the unconsolidated deposits along the Ohio River is hard and moderately mineralized. There is considerable variation in chemical character of water obtained from the various sources tapping these deposits. The pH of samples ranged from 6.5 to 8.2, hardness ranged from 130 to 300 mg/l, and the dissolved solids content ranged from 220 to 460 mg/l (table 5). The significance of these analyses in terms of the geologic controls of water quality and quantity, however, cannot be determined on the basis of available information.

River alluvium is the major source of industrial ground water in the Kanawha River basin. The alluvium, which consists of silt, sand, and gravel, overlies the bedrock along the Kanawha River valley from Charleston to Pt. Pleasant. The deposits range in thickness from a few feet near the valley walls to a maximum thickness of about 70 feet near the mouth of the river at Pt. Pleasant. The average thickness of the alluvium is about 55 feet, of which about 40 feet is saturated.

The alluvium is very heterogeneous and thus has a wide range of permeability. The more permeable sand and gravel generally occurs near the bottom of the deeper alluvium in contact with the underlying bedrock. At Eleanor, the sand and gravel deposits are in contact with the river, thus allowing water from the river to recharge the underlying alluvial deposits. Despite a lack of streamflow information for the reach of the Kanawha River below Charleston, it is likely that water is discharging from the underlying Monongahela Formation to the river through the alluvial sediments. Reported yields to industrial wells in the alluvium are more than 150 gpm.

Water from the Kanawha River alluvium is generally softer than the water from the bedrock, but commonly has high acidity and objectionable concentrations of iron (table 5).

Another area of unconsolidated alluvium in the Kanawha River basin is the abandoned pre-glacial Teays River Valley that extends from Scott Depot to Hurricane. This valley has an average depth of about 75 feet. The deposits consist mostly of poorly sorted clays, silts, and sands, and thus offer very little opportunity for the development of large ground-water supplies. No large water supplies are obtained from the unconsolidated deposits filling the valley, and most domestic wells are drilled through these deposits to obtain water from the underlying bedrock.

Bedrock Formations

The oldest formation, and perhaps the most productive, exposed in the Little Kanawha River basin is the Pottsville. The Pottsville is overlain by the Allegheny Formation in most of the basin, but is exposed at the surface in the headwaters of the Little Kanawha River near Kanawha Head. The Pottsville Formation ranges from 260 to more than 950 feet in thickness, and consists largely of permeable sandstone. The Allegheny Formation is also exposed in the headwaters area of the river. This formation ranges from 180 to more than 250 feet in thickness and consists primarily of sandstone with alternating beds of shale, limestone, and coal.

The Little Kanawha River has eroded through and is at a lower level than the Allegheny Formation in its outcrop area, and hence receives discharge from that formation from numerous springs along the high valley walls. It also receives discharge from the upper strata of the Pottsville Formation above Fallsmill, West Virginia.

Very little direct information is available about yields from wells drilled into the Pottsville and Allegheny Formations along the Little Kanawha River, but it is hydrologically significant that the highest sustained dry-weather flow of the Little Kanawha River is near Burnsville in the headwaters area. Since this discharge represents ground water from these formations, it is reasonable to assume that the Pottsville and Allegheny Formations offer considerable potential for the development of ground water.

Water in the Pottsville and Allegheny Formations in their outcrop areas is soft and only slightly mineralized. This is indicated by the chemical character of the Little Kanawha River at Burnsville. The pH of the surface water was about 7, the hardness as calcium carbonate was about 15 mg/l, the sulfate content was about 12 mg/l, and the total dissolved solids content was about 34 mg/l.

From below Fallsmill to Glenville, the Little Kanawha River flows in a deep valley cut into the Conemaugh and Monongahela Formations. These rocks consist primarily of sandstone, shale, and coal. The Conemaugh Formation ranges from 480 to more than 600 feet in thickness, and the overlying Monongahela ranges from 230 to more than 300 feet in thickness. Wells drilled into these formations yield as much as 50 gpm, but the average yield is about 10 gpm. That the Conemaugh and Monongahela are not as productive aquifers as the Pottsville and Allegheny Formations is evidenced by the decrease in the dry-weather yield per square mile of drainage area of the river at Glenville.

Ground-water samples were collected from two wells drilled into the Conemaugh Formation. The waters are alkaline with an average pH of 8.1, an average hardness of 25 mg/l, and an average total dissolved solids content of 350 mg/l. The Little Kanawha River at Glenville, which would reflect the chemical character of both the Monongahela and the Conemaugh, had a pH of 6.3, hardness of 70 mg/l, and total dissolved solids content of 110 mg/l.

From Glenville, the Little Kanawha River flows westward across rocks primarily of the Monongahela Formation to Burning Springs. Tributaries in this stretch of the river also have their headwaters in the Monongahela Formation. The dry-weather flow of the river at Grantsville is less than at Glenville indicating the Monongahela is not as productive an aquifer as the Conemaugh. From Grantsville to Burning Springs, the Dunkard Group overlies the Monongahela in the highland areas, but contributes little water to the river. The chemical quality of water taken from wells drilled into the Monongahela Formation showed the water to be slightly acid, and hard. The pH of the water was 6.4, hardness was 160 mg/l, and total dissolved solids was 240 mg/l.

At Burning Springs, the Little Kanawha River crosses the only major geologic structure in the basin, the Burning Springs anticline. This uplift and the subsequent erosion has exposed older rocks of the Conemaugh and Monongahela Formations at the surface. Discharge of water from these formations accounts for the increase in flow of the Little Kanawha River at Palestine. The Burning Springs anticline also brings the deeper, more mineralized water in the formations close to the surface. Well data are not currently available on the quality of ground water from these older formations in this area, but the quantity of water discharged is not great enough to materially affect the dissolved mineral content of the Little Kanawha River. The river at Elizabeth was soft and had a low dissolved solids content. The pH of the river was 7.5, the hardness was 49 mg/l, and total dissolved solids was 72 mg/l.

From the Burning Springs anticline north to Parkersburg, the bedrock formations are a part of the Dunkard Group of Pennsylvanian and Permian age. These formations are more than 500 feet thick and contain more shale and less sandstone than the other formations in the basin. Rocks of the Dunkard Group are the poorest aquifers in the basin, and generally yield less than 5 gpm to individual wells. Streams rising in the Dunkard Group have the lowest dry-weather flows of any streams in the basin.

In the headwaters area of the New River in North Carolina, the major sources of ground water are Precambrian gneisses and schists. Gneiss is a fairly dense rock and generally is not a dependable source of water. Where joints and fractures in the rock structure are enlarged due to solution by water, good supplies may be obtained. A dry hole may result, however, if a well misses these fractures or solution channels. A schist is usually a soft rock and easy to drill. Where fracture planes are developed in them, or become enlarged by weathering, rather large quantities of water may be stored in, or move through, these rocks.

Little information is available on yields from wells drilled into the Precambrian rocks in North Carolina, but a few scattered well logs indicate yields of more than 70 gpm may be obtained from the gneiss. Yields from the schists generally are smaller. Overflow from these rocks sustain a high flow in the New River, even during dry weather. This flow, which represents discharge from the aquifers, indicates that the gneiss and schist offer some potential for the development of ground water. The large flows also reflect the high precipitation over the area, which is greater than 50 inches a year.

In the southern part of western Virginia, near Galax, the rocks consist of granite gneiss, quartzite, conglomerate, and phyllite. Rocks of these types can be good sources of water if they have become extensively fractured. The large dry-weather flow of streams draining these metamorphic rocks indicates that they are fractured and yield significant volumes of water to the streams above Galax, Virginia. Analysis of available information concerning the yields of wells drilled into these rocks is currently underway as part of the Kanawha River Basin Comprehensive Survey.

North from Galax to the West Virginia line, the New River basin is underlain by tightly folded and faulted sedimentary rocks of Paleozoic age. These rocks consist mainly of dolomite, limestone, shale, sandstone, quartzite, and conglomerate. Uplift and erosion has left many of them exposed at the surface in long, narrow, northeasterly extending belts. Cambrian shales and dolomites are sources of ground water to wells in the area drained by the New River between Galax and Allisonia, Virginia. The drop in the per square mile discharge of the New River between Ivanhoe and Allisonia during dry weather indicates, however, that the Precambrian rocks along the north flank of the Blue Ridge have a higher potential for ground-water development than that of the Cambrian rocks. The flow of Big Reed Island Creek is sustained by discharge from the Precambrian rocks.

Claytor Lake extends across the entire outcrop of sandstones and shales of the Rome Formation between Allisonia and Radford, Virginia. Because the streams entering the area flow over many formations, the yield of the Rome Formation cannot be determined due to a lack of the large quantities of streamflow data that would be required at the many points of geologic significance. It is assumed that the Rome is not a source of large supplies of ground water adequate for industrial or municipal needs, because of the presence of impermeable shale beds in the formation. That the Devonian and Mississippian sandstones and shales lying west of Claytor Lake are also limited sources of ground water is shown by the relatively small flow of Peak Creek at Pulaski.

The Elbrook Dolomite outcrops under the downstream end of Claytor Lake at Radford. Records of unregulated streamflow for the period 1909 to 1915 show a large pickup in flow of the New River at Radford, thus indicating that the dolomite is a good source of ground water.

The area between Radford and Eggleston contains tightly folded rocks. Consequently many different rock types are exposed in a fairly short distance, and the river crosses the same rock sequence more than once. One of the first rocks the river crosses is the Rome shale of Cambrian age. The Chemung and Brallier shales of Devonian age, and the Maccrady Shale of Mississippian age probably are inadequate sources of water for other than small domestic needs. The Middle and Upper Ordovician limestones, and the Price Sandstone of Mississippian age are good sources of ground water, and discharge from these units accounts for the increase in flow of the New River at Eggleston.

From Eggleston to Glen Lyn, near the West Virginia line, the major rock units are the Copper Ridge Dolomite of Cambrian age, and Middle and Upper Ordovician limestones. That these rocks are good sources of water is evidenced by the fairly high flow of the New River between Eggleston and Glen Lyn. Several wells of the Celanese Company are reported to produce more than 1,000 gpm. A major fault crosses the area near Glen Lyn, but its effect on quantity or quality of water in the area cannot be determined on the basis of available data.

Within a few miles after the New River enters West Virginia and reaches the Appalachian Plateau, the flat-lying rocks crop out in much wider belts. From the state line to Hinton, the rocks are conglomerate, sandstone, and shale of the Hinton Formation. In the upstream areas of the Bluestone River, the sandstones and conglomerates of the overlying Bluestone Formation are good producers of ground water. This is shown by the relatively large

dry-weather flow of the Bluestone River at Spanishburg. However, from Spanishburg to the confluence of the Bluestone with the New River, the rocks are more shaly and yield less water to wells. This is shown by the decided decrease in dry-weather flow of the Bluestone River between Spanishburg and its mouth.

A few miles downstream from the mouth of the Bluestone River, the Greenbrier River empties into the New River at Hinton. The Greenbrier River flows southwestward along the flank of the folded Valley and Ridge Province rock strata, which controls the direction of flow of the river. The river flows across Silurian and Devonian limestones, sandstones, and shales. The limestone of Silurian age is undoubtedly a good source of water, and feeds tributaries flowing into the Greenbrier River. The fine sandstones and shales of Devonian age are poor sources of water and supply small quantities of water adequate only for domestic supply. The main stem of the Greenbrier River flows on Mississippian sandstones that yield fair amounts of water; however, at Marlinton there is a noticeable pickup in the dry-weather flow of the Greenbrier River as compared to its flow upstream at Durbin. This increase in flow may in part be attributed to the permeable sandstones that underlie the river, but most of the water comes from the Greenbrier Limestone that caps the uplands west of the river. Throughout the area north of Marlinton, numerous springs with flows as much as 500 gpm issue from the limestones and underlying sandstones. Analysis of a water sample taken at Marlinton showed the water to be very hard, 240 mg/l, and to have a total dissolved mineral content of 530 mg/l. The water was slightly alkaline with a pH of 7.2.

Near Anthony, in Greenbrier County, two small unnamed streams rise in the Mississippian sandstones, flow south for about 12 miles and then disappear into the cavernous Greenbrier Limestone. That the Greenbrier and other limestones in the area are cavernous and hence offer good possibilities for ground-water development is further suggested by the names of the local communities: White Sulphur Springs, Salt Sulphur Springs, Blue Sulphur Springs, Sinks Grove, and Fort Spring. Yields of water from these springs range from a few gallons a minute to more than 5,000 gpm. Only two water analyses are available from the limestone springs. One sample that was taken from the Helderberg Limestone was surprisingly soft and was only very slightly mineralized. The pH of the water was 7.1, the hardness was 84 mg/l, and total dissolved solids was only 92 mg/l. A sample taken from the Greenbrier Limestone was very hard, 290 mg/l, and moderately mineralized, 340 mg/l. The sample was also slightly alkaline.

North along the Kanawha River from Hinton to Gauley Bridge, large yields of water are obtained from wells drilled into the underlying sandstone and shale of the Bluestone and Pottsville Formations. The Pottsville Formation contains thick, coarse-grained, poorly cemented sandstones that are excellent sources of ground water. Average yield to wells from these rocks reportedly is over 100 gpm. A water sample taken from the Pottsville Formation at Victor showed the water to be moderately acid, pH 5.9, and very soft, 30 mg/l.

At Gauley Bridge, the Gauley River flows into the New River to form the Kanawha. Along the Gauley River, the predominant rocks are sandstones of the Pottsville Formation. Dry-weather flows of the upper Gauley River are relatively small because the headwaters are fed by the Hinton and Bluefield Formations, which have small discharges. The largest dry-weather flows in the upper reaches of the basin are recorded on the lower Williams and Cranberry Rivers. These two tributaries to the Gauley River drain coarse sandstones and conglomerates of the Bluestone Formation, which offers considerable potential for the development of ground-water supplies. There is a decided pickup in the dry-weather flow of the lower Gauley River, indicating that the Pottsville Formation discharges large volumes of water to the downstream reaches of the river. A sample of ground water taken from the Pottsville Formation near Summersville showed the water to be slightly acid and moderately hard. The pH of the sample was 6.8, and the total hardness was 110 mg/l.

In the central part of the basin, from Kanawha Falls to Charleston, the river flows over the coarse-grained sandstone and conglomerate of the Pottsville Formation, having completely eroded through the overlying Allegheny Formation. The Pottsville Formation ranges in thickness from about 400 to more than 1900 feet, and the Allegheny from about 115 to 250 feet in thickness. Both formations along this reach of the river are excellent aquifers and furnish most of the public ground-water supplies in the basin. The average yield to wells is about 120 gpm, and a few wells reportedly yield more than 500 gpm. Along the Kanawha River gorge above Charleston, numerous springs discharge from permeable zones in these rock formations into the river. Wells drilled to depths greater than 300 feet into the Pottsville Formation usually encounter highly mineralized water.

In a few small communities, public-water supplies are obtained from abandoned coal mines in the Pottsville Formation. The water is easy to obtain but may be of poor chemical quality. The towns of Coalburg and Kayford obtain their public water supplies from abandoned mines along Cabin Creek, and Rensford, from an abandoned mine near Campbell Creek.

At Charleston, mineralized waters are present close to the land surface along the Warfield anticline. Many large industrial users of ground water in the Charleston area abandoned their wells because of the high cost of treatment and the unsuitable quality of the water. The city of Charleston obtains its water from the Elk River.

From Charleston to Pt. Pleasant, the major consolidated rock formations are the Conemaugh and Monongahela. These formations consist of shale, siltstone, sandstone, and limestone. The Conemaugh is as much as 600 feet thick, and the Monongahela is about 300 feet thick. Because of the large amounts of shale and siltstone, little water can be obtained from these formations in the lower Kanawha, the average yield being only about 10 gpm. However, one well drilled into the Conemaugh Formation yielded more than 60 gpm. Wells that penetrate the more productive underlying Pottsville and Allegheny Formations generally yield highly mineralized water.

The low permeability of the Conemaugh and Monongahela Formations is also reflected in the smaller dry-weather flows of the surface streams in the area. Most of these streams have yields of less than .05 cfs per square mile of area drained, and the Pocatalico River at Sissonville had a dry-weather yield of only .007 cfs/sq. mi.

CURRENT STATUS OF GROUND-WATER INFORMATION

Reports that describe in rather broad terms the ground-water resources of the states have been published for West Virginia and North Carolina. The West Virginia report, prepared cooperatively with the U.S. Geological Survey, divides the state into major river basins and discusses in general terms the water resources within each basin. The North Carolina report, also prepared in cooperation with the Geological Survey, divides the state into physiographic units and also discusses in general terms the ground-water resources within each unit. The West Virginia Geological and Economic Survey, in cooperation with the U.S. Geological Survey, has also published a report on the ground-water resources of the Ohio River valley in West Virginia. Summary reports for the ground-water conditions in each county of Virginia is contained in the "Economic Data Summaries" that are published by the Virginia Division of Industrial Development and Planning.

In addition, the following more detailed reports discuss ground-water resources of the Little Kanawha-Kanawha River basins:

Doll, W.L., Meyer, Gerald, and Archer, R.J., 1963, Water resources of West Virginia: West Virginia Dept. of Natural Resources, Div. of Water, 134 p.

Doll, W.L., Wilmoth, B.M., and Whetstone, G.W., 1960, Water resources of Kanawha County, West Virginia: West Virginia Geol. and Econ. Survey Bull. 20, 189 p.

Wilmoth, B.M., ____, Ground water in Mason and Putnam Counties, West Virginia: West Virginia Geol. and Econ. Survey Bull. 32, in press.

Available data, including the present report on the ground-water resources of the Little Kanawha, Kanawha, and intervening Ohio River basins, are adequate only for general planning purposes in the few specific locations previously listed. This report shows in general the distribution and relative quantities of ground water present in the area, but is of inadequate scope for use in specific developments. Additional data are needed on the thickness and areal extent of the unconsolidated deposits in the major stream valleys, and their recharge-discharge relations with the overlying streams. This information would be particularly valuable in the Charleston, Parkersburg, and Pt. Pleasant areas where pollution of these

deposits by industrial and municipal wastes has caused abandonment of many wells. Considerably more data are needed to determine the depths and yields of fresh-water aquifers within the consolidated deposits. Such data could prove valuable in planning means to augment streamflow during periods of low flow, and would also prove valuable in determining and delineating areas of geologic uplift and its relations to shallow salt water deposits.

A much more detailed study of ground-water distribution and potential as well as additional ground-water quality information is currently in progress as part of the Kanawha River Basin Comprehensive Survey. The scope of that Survey is broad enough to include detailed analysis of numerous well records and other hydrologic data that is available from state agencies for the Kanawha basin sections of North Carolina, Virginia, and West Virginia.

MANAGEMENT CONSIDERATIONS

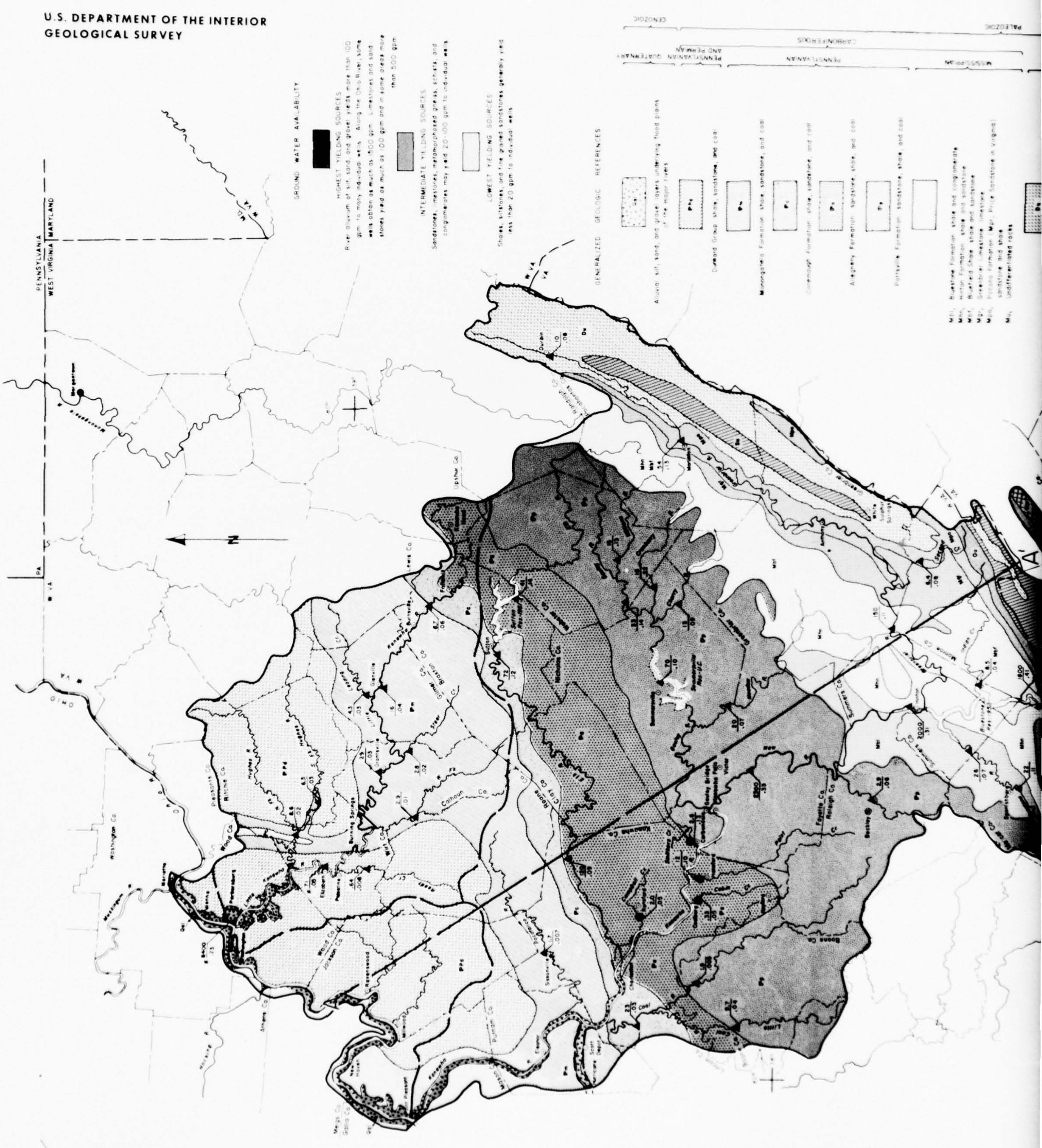
This study of the Little Kanawha, Kanawha, and intervening drainage area to the Ohio River basin reveals that the area has considerable potential for future water-resource development. The ground-water resources, however, are not uniformly distributed; hence, planning for the future development and management of these resources requires a foundation of detailed hydrologic information. Some of the more serious problems of the basin are:

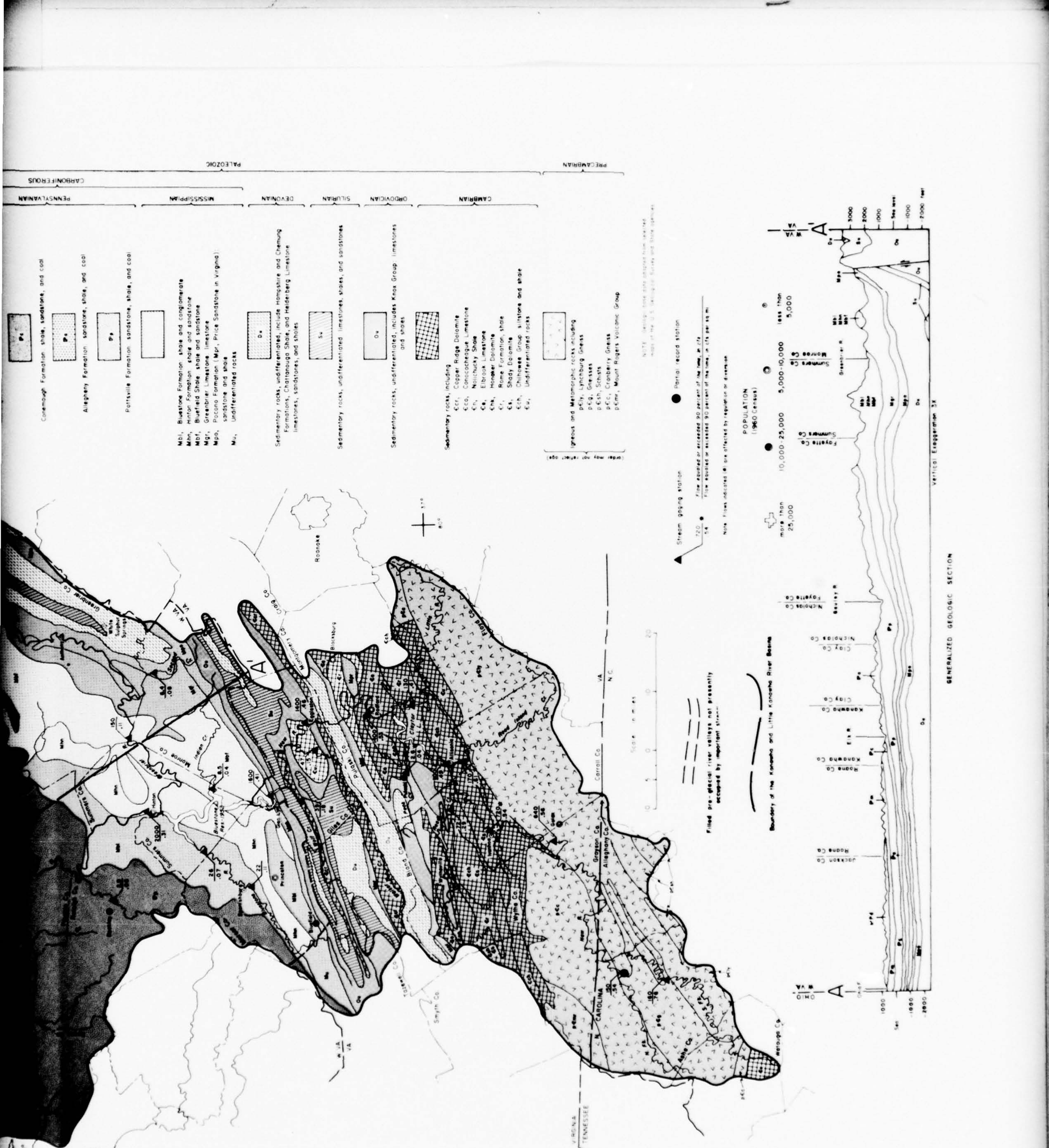
Pollution of water sources: The Kanawha River above Charleston is of generally poor quality, having been polluted by industrial wastes in its reach through Kanawha County by such constituents as ammonia and nitrite, and a deficiency of dissolved oxygen during the low-flow, late summer months. The possible use of ground water to augment low flows does not appear practicable because the river is a more efficient drain of the aquifers in the area than any wells possibly could be. A possible hydrologic solution to this problem might lie in low-flow augmentation by use of waters to be stored in the Summersville Reservoir or in the Big Bend Reservoir, if that project is activated.

According to a report published by the West Virginia Geological and Economic Survey, manmade pollution of ground-water resources is also a threat as shown by instances of pollution of wells by industrial wastes in Kanawha County. However, the nature and delineation of ground-water pollution within the area of this report have not been thoroughly investigated. Such an investigation would obviously be a requisite to effective remedial action.

Saline-water at shallow depths: At several places in the lower portions of the Little Kanawha and Kanawha River basins, saline ground water is present at rather shallow depths, especially along the Burning Springs anticline, and in the Charleston area. This appears to be due to naturally discharging ground water. Delineation of such discharge areas is needed if problems associated with highly mineralized waters are to be avoided. The present investigation is of inadequate scope to accomplish this, but it is recommended that the detailed Kanawha basin study begun in fiscal year 1964 include investigations of the hydraulic regimen of the basin as a guide toward effective basinwide water-resource planning.

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY





KANAWHA AND LITTLE KANAWHA RIVER BASINS
SOURCES OF GROUND WATER

PLATE 13

2

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 6

SCIOTO RIVER BASIN
(Including northside drainage area to the Ohio River between Pt. Pleasant and Maysville)

By

Morris Deutsch and George D. Dove

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

SCIOTO RIVER BASIN
(Including northside drainage area to the Ohio River
between Pt. Pleasant and Maysville)

CONCLUSIONS

The ground-water resources of the Scioto basin have considerable potential for future development and can play an important role in the solution of the basin's water problems. The chief water problems of the basin, as indicated by studies of the Ohio Division of Water and by conferences of state and federal water agencies, are concerned with obtaining adequate quantities of suitable quality for a wide variety of uses, some of which are conflicting.

The chief sources of ground water in the basin, in order of estimated decreasing potential, are as follows:

1. Sand and gravel in the valley of the Scioto River below Columbus.

2. The limestone aquifers in the northwestern and western parts of the Scioto basin, and in the northern part of the basin of Ohio Brush Creek.

3. Glacial outwash deposits associated with widely-distributed moraines.

4. Sand and gravel in the buried pre-glacial Teays and Mt. Vernon Valleys, excluding the reach along the Scioto River.

5. Sand and gravel in lower reaches of post-glacial valleys tributary to the Scioto River.

6. Sandstone aquifers in the northeastern part of the Scioto basin and in parts of the basins of Raccoon and Symmes Creeks.

Ground-water sources have been developed intensively for supply purposes at points of need only in limited metropolitan and industrial areas. In broad areas of the basin, the ground-water resources are relatively untapped, and from a technical standpoint are available for regional development for future needs of any type. The wide distribution of the aquifers of the basin indicates their potential value for uses other than local water supplies. Possible applications include the use of ground water for low-flow augmentation, dilution of waste-carrying waters, sewage assimilation, and for replenishment of surface reservoirs. Use of ground water for

purposes such as these could materially aid in the solution of water-quality as well as water-quantity problems. In addition, tapping of unused aquifers on a regional basis would provide underground storage capacity prior to periods of natural recharge, and conceivably could reduce flood discharges.

PHYSIOGRAPHY AND DRAINAGE

The area covered by this report includes the Scioto River basin and adjacent areas in Ohio drained by the Ohio River between Pt. Pleasant and Maysville, including the drainage basins of Raccoon, Symmes, Pine, and Ohio Brush Creeks (pl. 14). The glacial and alluvial deposits in and along both sides of the Ohio River between Pt. Pleasant and Maysville are described in the section covering the Guyandotte, Big Sandy, and Little Sandy River basins.

The Scioto basin has a drainage area of about 6,500 square miles in south-central Ohio. The total area covered by this report is about 8,000 square miles. The northern two-thirds of the basin was covered by a succession of continental glaciers during the Pleistocene Epoch (Ice Age), which covered the Paleozoic bedrock formations of limestone, dolomite, shale, and sandstone with glacial drift and greatly affected the hydrology of the basin. The bedrock formations as well as the glacial drift include major aquifers. The principal aquifers are widely distributed throughout the basin, and hence are available for developments to meet current or future needs.

The Scioto River rises in outwash deposits along the Wabash Moraine near Kenton, Ohio, in the northwest corner of the basin. The river flows in a southeastward direction along the moraine almost to Marion where it meets the Little Scioto River. From Marion it flows southward in a glaciated valley past Delaware, Columbus, and Circleville to Chillicothe. Its principal tributaries in this reach are the Olentangy River, Alum, Big Walnut, and Walnut Creeks entering from the east; and Bokes, Mill, Big Darby, Deer, and Paint Creeks entering from the west. All of these tributaries drain glacial deposits within the Scioto basin. Columbus, the largest city and water user, is on the Scioto River near the center of the basin, in the vicinity of the mouths of the Olentangy River and Big Walnut and Alum Creeks.

South of Chillicothe, the Scioto flows in a broad valley it has cut through the western part of the Appalachian Plateau to Portsmouth. At Portsmouth it enters the Ohio River about 360 miles downstream from Pittsburgh. Salt and Scioto Brush Creeks drain unglaciated portions in the southern part of the Scioto basin.

Raccoon and Symmes Creeks drain sandstone formations of the Appalachian Plateau southeast of the Scioto basin. The Ohio Brush Creek drains limestone strata to the southwest of the Scioto basin.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

The unconsolidated sediments of the Scioto basin may be classified as glacial drift, alluvium, and combinations thereof. All are important sources of ground water. Sand and gravel layers or lenses comprise the most permeable portions and hence the best aquifer materials of each of these major types, regardless of origin.

The glacial drift consists of till, deposited directly by the ice, which is a relatively poor source of water, and outwash deposited by melt waters from the ice. Outwash deposits are generally a good source of water. The distribution of the outwash deposits has a pronounced effect on the availability of water in the basin and the flow characteristics of the streams, especially during dry weather. Extensive alluvial deposits of pre-glacial and glacial streams are present in the basin, and contain large quantities of water in storage. The alluvial, as well as the glacial deposits, are readily accessible for development by wells.

There are widely distributed areas of glacial outwash deposits in the basin where future ground-water developments are possible:

(1) Along the western margin of the basin from Kenton to Washington Court House.--The headwaters of the Scioto River, Rush, Mill, Big Darby, Little Darby, Deer, Paint, and Rocky Fork Creeks are fed by ground water discharging from these deposits. These glacial deposits range from about 60 to more than 250 feet in thickness. Dry-weather discharges (based on the flows exceeded 90 percent of the time) in the headwaters of these streams are as much as 0.11 cfs per square mile of drainage area (pl. 14). Dry-weather discharge of these streams merely represents overflow from the aquifers and is no indication of the volume of water in storage, but because of the concentrations of glacial sediments, it is reasonable to assume that the area has considerable potential for development of ground water.

(2) Along widely distributed morainal fronts throughout the basin.--Outwash deposits along the fronts of the Wabash, St. Johns, Broadway, and Cuba Moraines discharge ground water into reaches of the upper Scioto River, Rush Creek, Mill Creek, and Rocky Fork Creek east of Hillsboro, respectively (pl. 14). These deposits are as much as 100 feet, and commonly more than 30 feet thick. Each of these areas shows promise for future ground-water development. These potential sources of supply are indicated by the high sustained low-flow of the streams, ground-water pumpage data, geologic maps, and well log information.

East of the Scioto River similar outwash deposits, from 40 to 150 feet thick along the fronts of the north-south trending Broadway and Powell moraines, discharge ground water into reaches of Whetstone Creek above Mt. Gilead, Alum Creek south of Mt. Gilead, and Big Walnut Creek above Hoover Reservoir. The sustained dry-weather flow of these streams also shows these areas to have potential for ground-water development comparable to the above-listed areas lying west of the Scioto River. Kinnikinnick Creek has the highest sustained low-flow per square mile of any stream in the Scioto basin, but because the station is near the mouth of the creek, the yield may be largely attributable to underflow through the Scioto River alluvium. This stream drains an area bordering the front of the Cuba moraine east of the Scioto River.

(3) Thick deposits of glacial outwash and alluvium in the central part of the basin.--West of the Scioto River, outwash and alluvial deposits are more than 200 feet thick in places. In Madison and Pickaway Counties, till deposits apparently are interbedded with water-bearing sand and gravel. This is evidenced by the relatively high dry-weather yields of Big Darby and Deer Creeks in comparison to other creeks draining areas shown on geologic maps as till plain. Near their mouths, Big Darby and Deer Creeks each discharge about 25,000 gpd per square mile for each of their 551 and 411 square miles of drainage area, respectively.

The water in the unconsolidated glacial deposits is of the calcium-magnesium bicarbonate type, is generally high in dissolved mineral content, and very hard. Depending on the use, therefore, some degree of treatment may be necessary. The average hardness is about 350 to 400 mg/l, and total dissolved solids average about 550 mg/l (table 6). On the other hand, however, the water is almost always clear and free of bacterial contamination. It has a rather uniform temperature of about 53°F. and therefore is superior to surface water in various applications.

The most important present and potential sources of ground water are sand and gravel deposits in the valley of the Scioto River between Columbus and its mouth at Portsmouth. The Scioto River sediments extend about 90 miles southward from Columbus, are several miles wide, and in many places are more than 100 feet thick. The storage capacity of this volume of sediments is on the order of hundreds of billions of gallons, or many times the capacity of the largest surface reservoir in the basin.

From Circleville south to Piketon, the Scioto River follows the course of the pre-glacial Teays River. Glacial melt waters filled this valley and tributary valleys to their present level with sand and gravel deposits into which the Scioto River and its tributaries have cut their present channels. Individual wells drilled into these deposits yield as much as 1,500 gpm.

TABLE 6.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE SCIOTO RIVER BASIN.[a]

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (^{o}F)
				Unconsolidated Sediments					
Scioto River glacial and alluvial sediments below Columbus, Ohio	10-100	350-1500	50-125	225-375	---	3-75	.1-5.0	275-500	48-54
Glacial outwash along morainal fronts	10-15	10-50	50-150	325-525	25-150	5-50	.1-3.0	330-600	53-58
Teays and preglacial valley alluvium (excluding the reach along the Scioto River)	10-30	10-25	30-100	50-300	5-125	5-20	.5-15	75-400	51-54
Glacial and alluvial sediments in Scioto River tributaries	10-20	10-20	20-90	300-500	25-175	5-40	.1-3.5	350-650	53-56
				Bedrock Formations					
Pennsylvanian System: Conemaugh, Allegheny, and Pottsville Formations (sandstones)	---	5-20	75-750	70-225	---	4-200	.05-1.0	450-700	51-59
Mississippian System, undivided, (sandstones and limestones)	---	20-100	90-225	50-300	50-125	5-30	.5-15	75-500	52-54
Devonian and Silurian Systems: Columbus and Delaware Limestones, Bass Island and Niagara Groups (limestones and dolomites)	---	25-250	80-150	500-700	---	5-25	.1-3.0	300-1000	52-55

[a] Including northside drainage area of the Ohio River between Ft. Pleasant, West Virginia, and Maysville, Kentucky.

Wells drilled into the outwash deposits in the Scioto valley at Circleville yield a like amount and five large diameter radial collectors at Chillicothe yield a total of 35 mgd (54 cfs). Despite these and other large withdrawals from the sand and gravel in the valley, the dry-weather pick-up of the Scioto River south of Columbus, which is sustained chiefly by discharge of ground water, averages more than 1.2 cfs per mile of valley length.

Prior to Pleistocene glaciation, the Scioto basin was drained by an ancient large river called the Teays. The trace of the major Teays drainage pattern is indicated on plate 14. The Teays River flowed north from the Portsmouth area to near Circleville, and from there northwestward past London. The pre-glacial valley of the Teays River, where it is now occupied by the Scioto River, is the source of the largest sustained ground-water yields in the basin. The Scioto River alluvium, however, fills only that part of the ancient valley from Piketon north to near Circleville.

Northwest across the basin from South Bloomfield, the Teays valley is filled mainly with silts and clays, and--except for local deposits of sand and gravel such as those found at London--yields to wells generally are less than 50 gpm. At London, where the unconsolidated sediments are over 250 feet thick, individual wells yield as much as 400 gpm. East from South Bloomfield, the course of a major Teays River tributary, the Mount Vernon River, is marked by the present course of Walnut Creek. As indicated by the rather high sustained low-flow yields per square mile of Walnut Creek from South Bloomfield to Baltimore, the area is underlain by as much as 340 feet of permeable sands and gravels, and is therefore a promising area for future ground-water developments.

The lower reaches of Big Walnut and Alum Creeks, the Olentangy River and the Scioto River above Pickaway County, also contain permeable sand and gravel deposits of glacial and pre-glacial origin. The city of Columbus has facilities for pumping 10 mgd from five wells drilled into typical buried valley deposits along the course of Alum Creek.

Bedrock Formations

The water-bearing consolidated rocks in the report area consist chiefly of limestones and sandstones of Silurian and Mississippian ages, respectively (pl. 15). Although these rocks store appreciable quantities of water, their effect on the dry-weather flow of the streams is obscured by effects of overlying glacial drift, except where they are at or near the surface. Therefore, streamflow data have not been used herein to determine their water-yielding characteristics. The drainage areas of Raccoon, Symmes, and Pine Creeks are underlain by sandstone, shale, and coal strata of Pennsylvanian age. The Ohio Brush Creek basin is underlain by limestone, dolomite, and shale formations of Silurian age. The hydrologic characteristics of the bedrock aquifers are indicated by pumpage data, geologic maps, and well-log information.

In the northeast and east-central parts of the basin, sandstone strata of Mississippian age comprise the predominant consolidated rock aquifers (pl. 15). These sandstones, which are as much as 380 feet in aggregate thickness, yield as much as 100 gpm to individual wells. The average yield of wells in these rocks, however, is about 10 to 20 gpm. South of Pickaway and Hocking Counties, the sandstones become thinner and shales become the predominant type of consolidated rock. These shales are relatively impermeable and numerous dry holes are recorded. A few thin Pennsylvanian sandstone layers that may supply adequate quantities of water for domestic use are present in the southeastern part of the Scioto basin, chiefly in Jackson County. Generally these sandstones lie above the drainage of the surrounding area and, consequently, during dry periods there are frequent reports of wells drilled into them going dry.

In Raccoon, Symmes, and Pine Creek basins, where the bedrock surface consists predominantly of sandstone, shale, and coal, yields of as much as 45 gpm are reported from wells tapping the Conemaugh, Allegheny, and Pottsville Formations. The Monongahela Formation, which forms the bedrock surface in a small area along the Ohio River downstream from Gallipolis, is a poor source of water.

The dissolved mineral concentration of water from the sandstones is generally lower than that from the glacial drift. The dissolved solids concentrations for most of the samples listed in "Ohio Water Inventory" Report 17 (Ohio Division of Water, 1963) average from about 300 to 350 mg/l (table 6). Hardness averages about 200 to 250 mg/l.

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The lower reaches of Big Walnut and Alum Creeks, the Olentangy River and the Scioto River above Pickaway County, also contain permeable sand and gravel deposits of glacial and pre-glacial origin. The city of Columbus has facilities for pumping 10 mgd from five wells drilled into typical buried valley deposits along the course of Alum Creek.

Limestones and dolomites of the Niagara and Bass Island Groups of Silurian age comprise the principal bedrock aquifers in the western and northwestern portion of the basin. These rocks range in thickness from about 320 to 385 feet (pl. 15). Although wells tapping this aquifer generally yield less water than the more permeable glacial-drift aquifers, the Bass Island Group is an important source of water for industrial and municipal use because of its widespread distribution. Most industrial and municipal wells tapping this aquifer in Kenton, Marion, and Marysville have sustained yields of from 250 to 400 gpm.

These limestones dip at about 25 feet per mile in a general easterly direction (Stout, 1941), and underlie the entire eastern part of the basin. In the north-central part of the Scioto basin, between Marion and Columbus, the Bass Island Group is overlain by the Columbus and Delaware Limestones of Devonian age, an important source of ground water in the area. East of a north-south line running approximately through Columbus, the limestone and dolomite formations are overlain by as much as 700 feet of impermeable Devonian shales. Large quantities of water undoubtedly are contained in the limestones in the eastern part of the Scioto basin, but the formation is not tapped for water supply because of the relatively great depths involved in drilling (as much as 1,100 feet) and because the water is known to be highly mineralized.

In the central and southern parts of the Scioto basin, west of the Scioto River, and in the area drained by the Ohio Brush Creek, the limestone formations become thinner, and shales and dolomite become the predominant rock types. Because cracks, crevices, and solution channels that permit the free flow of water from one part of the formation to another are less likely to occur in the dolomites and shales, yields to wells from these rocks are less than those from the thick limestones farther north.

Water supplies obtained from the limestones in the Scioto River basin are generally more mineralized than water from the glacial deposits and sandstone formations. Water in the limestones west of the Scioto River has an average hardness of between 600 and 800 mg/l. Farther east, at Cheshire in Delaware County, water from a 494-foot deep well in limestone contained 16,000 mg/l of dissolved solids. At greater depths even this high concentration may be exceeded.

CURRENT STATUS OF GROUND-WATER INFORMATION

Reconnaissance maps of ground-water availability have been published by the Ohio Division of Water (1958) for the entire state. The Division of Water also published water inventory reports for the Scioto River basin (1963) and the Ohio Brush Creek basin (1960). Much of the streamflow data contained herein was published also by the Division of Water (Cross and Hedges, 1959).

Following are bibliographic references for the more important publications on ground water and related subjects for the area covered by this report:

Cross, W.P., and Hedges, R.E., 1959, Flow duration of Ohio streams: Ohio Div. Water Bull. 31, 152 p., 22 pls.

Ohio Division of Water, 1958, Ohio water plan inventory project: Ohio Div. Water, Underground Water Resources Maps L 2-3, M 1-17, N 1-5.

______ 1960, Water inventory of the Ohio Brush, Eagle, Straight, and Whiteoak Creek Basins: Ohio Div. Water Rept. 15, 50 p.

______ 1963, Water inventory of the Scioto River Basin: Ohio Div. Water Rept. 17, 76 p.

Schmidt, J.J., 1954, The water resources of Ross County, Ohio: Ohio Div. Water Inf. Circ. 4, 25 p.

______ 1958, The ground-water resources of Franklin County, Ohio: Ohio Div. Water Bull. 30, 97 p.

Smith, R.C., and Schmidt, J.J., 1953, The water resources of Pike County, Ohio: Ohio Div. Water Inf. Circ. 1, 15 p.

Stout, Wilber, 1941, Dolomites and limestones of western Ohio: Geol. Survey of Ohio, 4th ser., Bull. 42.

Walker, A.C., 1953, The water resources of Jackson County, Ohio: Ohio Div. Water Inf. Circ. 3, 15 p.

Walker, A.C., and Schmidt, J.J., 1953, The water resources of Scioto County, Ohio: Ohio Div. Water Inf. Circ. 2, 17 p.

Walker, A.C., and others, 1965, Ground water for industry in the Scioto River Valley: Ohio Div. Water Buried Valley Inv. Rept. 1.

MANAGEMENT CONSIDERATIONS

The value of the ground-water resource of the Scioto basin--and elsewhere--is severely limited if use is to be made of it solely for purposes of water supply at the point of need. Although it cannot be readily calculated, the volume of ground water in the aquifers of the basin is obviously many times greater than the volume of surface water, and hence offers intriguing possibilities for basinwide management.

During the severe drought suffered in the basin during the second half of 1963, the city of Columbus began pumping ground water from wells tapping the Alum Creek alluvium in order to avert an impending water shortage. Establishment of well fields tapping some of the more prolific aquifers cited above could augment supplies for some very important uses normally supplied from surface-water sources. For example, ground water could be pumped into streams in the northeast and northwest parts of the basin to supplement dry-weather streamflow and help replenish the reservoirs above Columbus if needed. This would provide the added advantage of providing some underground storage capacity prior to wet periods. During wet periods when supplementary supplies are not needed, pumping would cease and the aquifers would be naturally recharged.

There is a large resource of water available in the Scioto River alluvium below the reservoirs serving the Columbus area that may be able to support pumping for sewage dilution and general flow-augmentation purposes when it is desirable to release minimum amounts of water from the reservoirs.

The chief aquifer of the basin, the Scioto River alluvium, has the Scioto River available for recharge. Because of its great storage capacity and the large quantities of recharge water available, exploitation by induced recharge facilities would tend to be limited only by the quality of the waters of the Scioto River and the infiltration capacity of the sediments; and not by the quantities of water stored in the aquifer. Facilities requiring large quantities of water, such as the Atomic Energy Commission's installations at Piketon, obtain adequate supplies along the Scioto River valley below Columbus. Induced recharging effectively filters surface water through relatively great thicknesses of sediments and removes most bacterial and other contaminants, although it may permit the passage of dissolved stable chemical compounds with the percolating water.

In summary, if the full potential of the water resources of the Scioto River basin is to be realized, systematic exploitation and management of the aquifers on a regional basis will be necessary. Maximum benefits cannot be derived from the basin's water resources if management programs fail to take advantage of the underground water sources and storage potential within the basin.

U.S. DEPARTMENT OF THE INTERIOR
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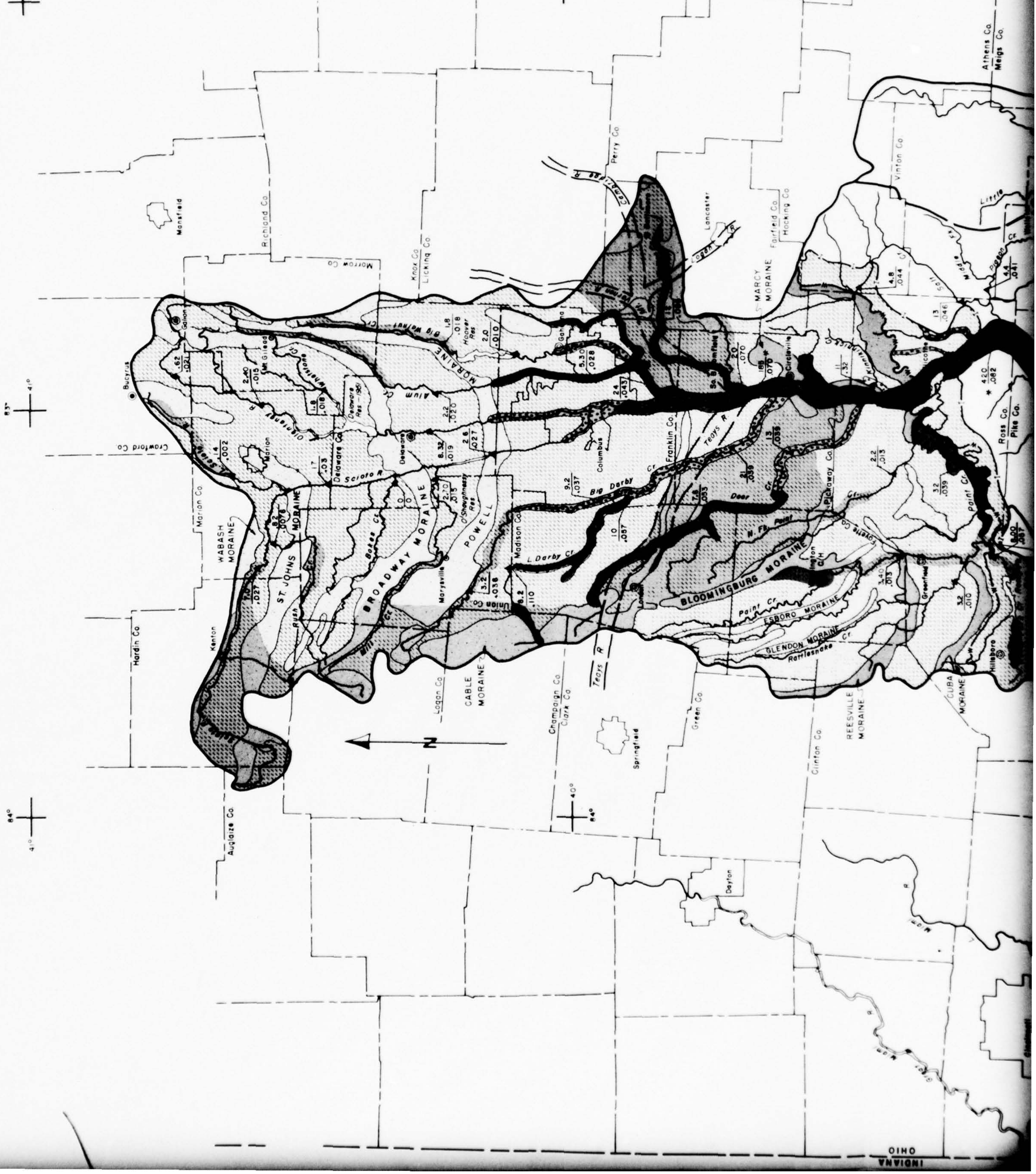
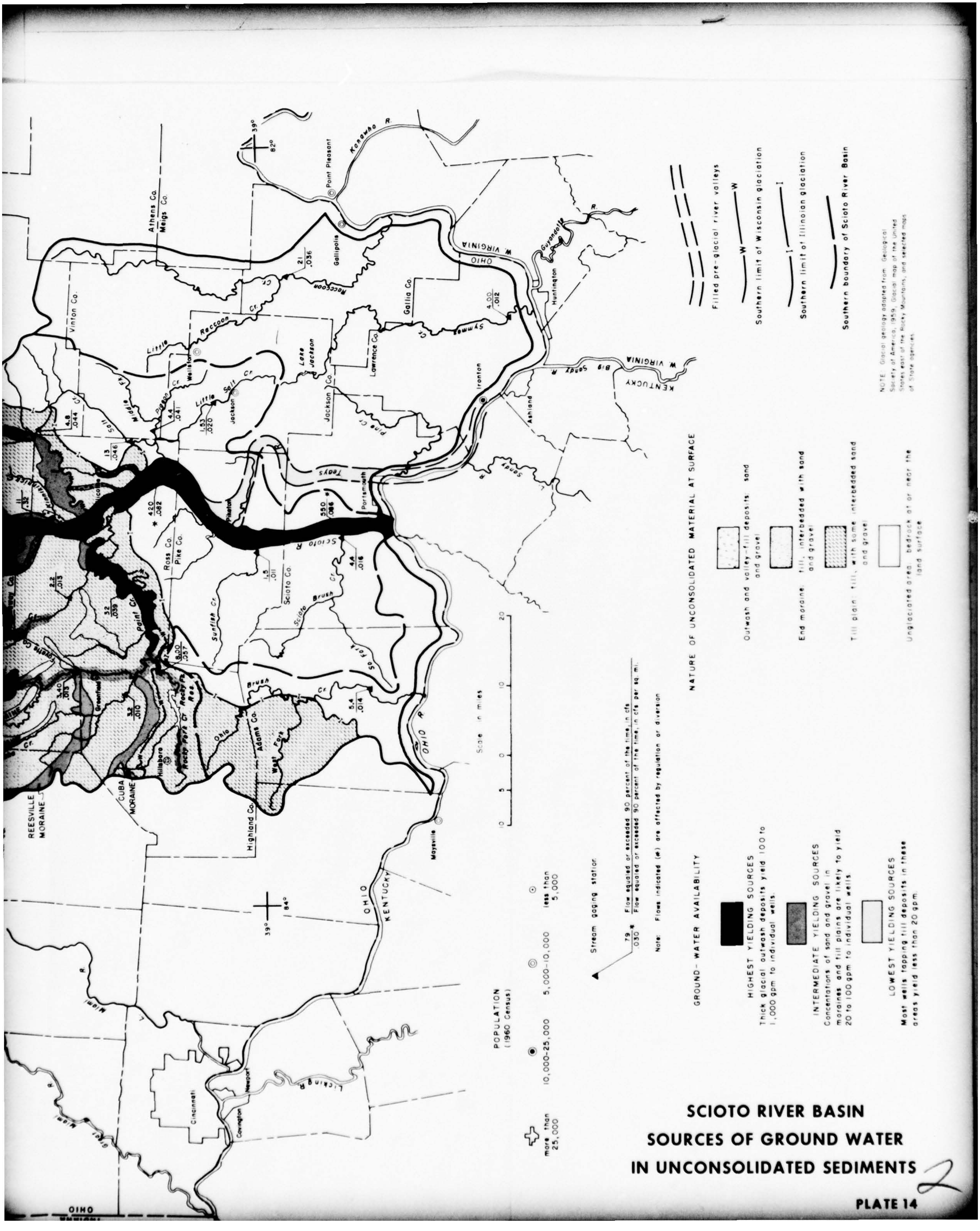
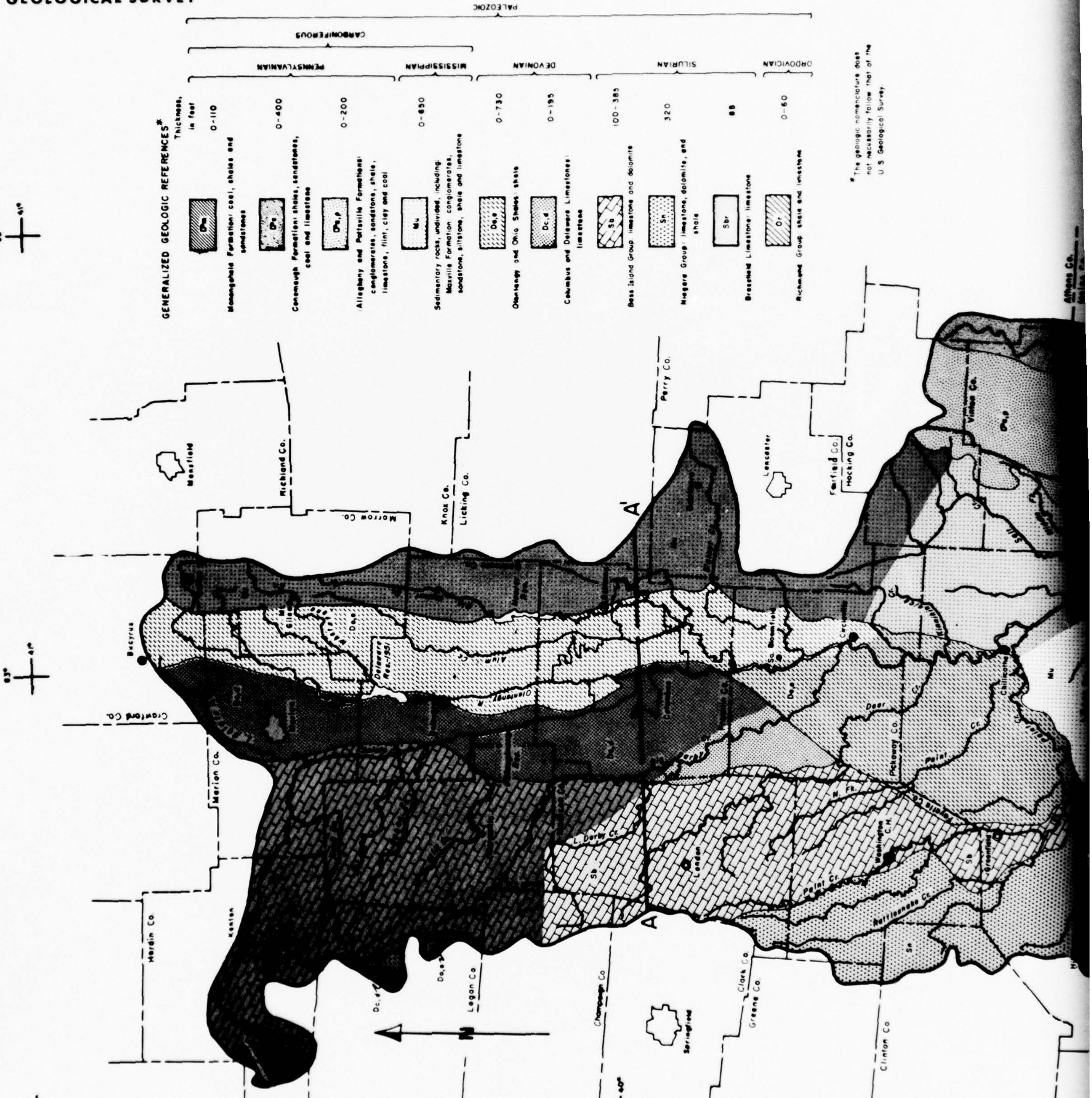


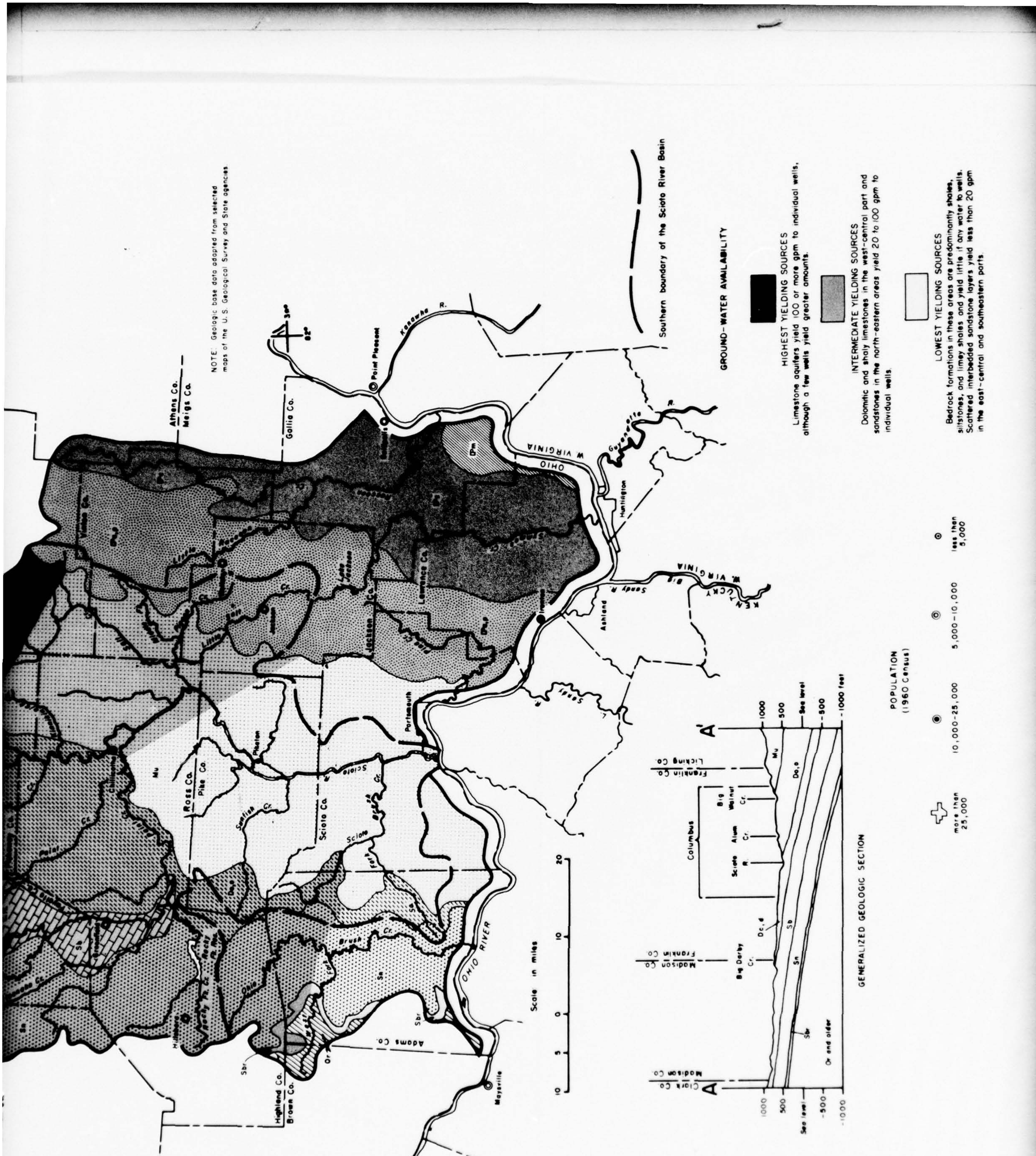


SCIOTO RIVER BASIN
SOURCES OF GROUND WATER
IN UNCONSOLIDATED SEDIMENTS

PLATE 14

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY





SCIOTO RIVER BASIN
SOURCES OF GROUND WATER
IN BEDROCK FORMATIONS

2

PLATE 15

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 7

GUYANDOTTE, BIG SANDY, AND LITTLE SANDY
RIVER BASINS
(Including southside drainage area to the Ohio River and
Ohio River alluvium between Pt. Pleasant and Maysville)

By

J.C. Wallace, R.A. Shamsi, and Morris Deutsch

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

GUYANDOTTE, BIG SANDY, AND LITTLE SANDY RIVER BASINS

CONCLUSIONS

Large supplies of ground water are available from two principal sources within and near the areas drained by the Guyandotte, Big Sandy, and Little Sandy Rivers. By far the greatest potential for future development is offered by the glacial and alluvial sediments in the valley of the Ohio River. Smaller, but significant, supplies of ground water of suitable quality for most uses are available for development also from sandstones of the Pottsville and Allegheny Formations. Small to moderate supplies, adequate for domestic or other small uses, may be obtained over much of the remainder of the report area from less permeable sandstone units of the Pennsylvanian System, limestone strata of the Mississippian and Devonian Systems, and alluvium in the valleys of streams tributary to the Ohio River.

The two principal aquifers described herein are sources for possible large-scale development. In decreasing order of potential, they are as follows:

1. Glacial and alluvial sediments in the Ohio River valley along the entire reach from Pt. Pleasant to Maysville, on the Ohio side as well as on the West Virginia and Kentucky side of the river.

2. Sandstone strata of Pennsylvanian age included in the Pottsville and Allegheny Formations, especially in the southern portion of the report area, but mainly in the stream valleys.

PHYSIOGRAPHY AND DRAINAGE

The ground-water situation described herein is for the area of the Ohio Basin draining to the Ohio River from the south between Pt. Pleasant, W. Va., and Maysville, Ky., as well as the Ohio River alluvium underlying the floodplain on both sides of the river along this reach. The area covers approximately 7,500 square miles in West Virginia, Kentucky, Virginia, and Ohio. The principal streams tributary to the Ohio in this area are the Guyandotte, Big Sandy, and Little Sandy Rivers.

The Guyandotte River, Twelvepole Creek, Big Sandy River, Little Sandy River, and Tygarts Creek basins and the Ohio River main stem from Pt. Pleasant to Portsmouth, Ohio, are in the Kanawha physiographic section of the Appalachian Plateau. The remaining portion of the report area, from Portsmouth to Maysville, includes the drainage basins of Laurel and Salt Lick Creeks, and is in the Lexington Plain of the Interior Low Plateau. The Kanawha section in Kentucky is referred to as the Eastern Coal Field, and the northeastern part of the Lexington Plain is called the Knobs. In this report, the Kentucky terminology is used.

The Guyandotte River rises in Wyoming County, W. Va., and flows westward in narrow, steep-sided valleys for about 35 miles until it turns northwestward through the coal mining regions of Logan County. From Logan, W. Va., the river drains the flatter terrain of Lincoln and Cabell Counties. Just south of Huntington, the Mud River, with a drainage area of 360 square miles, joins the Guyandotte which then empties into the Ohio River at Huntington. The Guyandotte River is 166 miles long and has a drainage area of 1,680 square miles.

Levisa Fork, the headwaters of the Big Sandy River, rises in a rugged, hilly area of Buchanan County, Va., and flows northwestward into Kentucky. At Millard, Ky., Russell Fork empties into the Levisa. From Millard, Levisa Fork continues its northwestward flow through Pikeville, Prestonburg, and Paintsville, where each city in turn taps the river for its municipal supply. From Paintsville, the river changes to a more northerly direction to its confluence with Tug Fork to form the Big Sandy River at Louisa, Ky. Levisa Fork has a length of 160 miles and a drainage area of 2,325 square miles.

New multi-purpose reservoirs are being constructed by the Corps of Engineers on Levisa Fork at Fishtrap, Ky., and on the North Fork Pound River and Pound River in Virginia. Dewey Reservoir at Van Lear, Ky., is a flood-control structure on Johns Creek, which empties into Levisa Fork just south of Paintsville, Ky.

Tug Fork, the major eastern tributary of the Big Sandy River, rises in McDowell County, W. Va., in the same rugged type of terrain as Levisa Fork. Between Wharncliffe, W. Va., and Louisa, Tug Fork forms the West Virginia-Kentucky State line for a distance of 93 miles. The two largest towns along this reach, Williamson and Kermit, W. Va., tap Tug Fork for their municipal water supply. Tug Fork has a total length of 154 miles, and a total drainage area of 1,555 square miles, of which 933 square miles is in West Virginia, 476 square miles in Kentucky, and 146 square miles in Virginia.

The area drained by Levisa and Tug Forks is predominantly a coal-mining region, although there is some oil and gas production in the basin. All of the larger towns are located in valley bottoms on narrow floodplains which offer the best location for highways and railroads. In the lower reaches of the basin, where the topography becomes more moderate and rolling with a wider floodplain, there is some farming and industry.

The Big Sandy River forms the West Virginia-Kentucky State line along its entire course of 27 miles to Ashland, Ky., where it empties into the Chio River. Its drainage basin covers an area of 4,290 square miles. Excluding the Ohio River main stem, most of the industry in the report area is located along the Big Sandy River and includes refineries, chemical plants, and lumber mills.

The Little Sandy River and Tygarts Creek are in the northern part of the Eastern Coal Field of Kentucky. The Little Sandy River has a drainage area of about 720 square miles. Tygarts Creek, which is roughly parallel to the Little Sandy River, drains an area of 340 square miles.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

The valley of the Ohio River between Pt. Pleasant and Maysville is partly filled with glacial sediments transported by the Allegheny, Beaver, Muskingum, and Scioto Rivers, and alluvium from the dissected unglaciated plateaus on both sides of the Ohio River. Sediments in the Ohio River valley consist principally of outwash sand and gravels of glacial origin, overlain by a layer of fine alluvial material composed of silt and clay, which are more recent deposits of the Ohio River. These sediments comprise an aquifer of about 145 miles in length, and about 1 to 2½ miles in width (pl. 16). The sand and gravel deposits range from about 60 to 100 feet in thickness and form a highly transmissive aquifer with great potential for future development. The overlying silts and clays vary in aggregate thickness from a few feet to 40 feet, and average about 10 feet. These sediments are of low permeability but allow significant percolation of water from the river and precipitation, which are the main sources of recharge to the underlying sands and gravels. The alluvium holds hundreds of billions of gallons of ground water of good quality, which is many times the total storage capacity of Dewey Reservoir in the Big Sandy basin.

The results of borings indicate that the thickness of the glacial and alluvial sediments vary considerably throughout the valley. Beneath the higher river terraces, the sediments may be more than 100 feet thick, but below the normal pool stage, which is important to wells being recharged through induced infiltration, the thickness varies from 10 feet to more than 50 feet. More extensive study would be required to assess the full contribution of Gallipolis and Greenup lock and dam to the ground-water reservoir along the Ohio River. The general effect of these impoundments has been to increase the saturated thickness of the aquifer in their respective reaches. What is more important is that these locks and dams, in the event of large-scale ground-water development in the area, provide a source of ground-water recharge at a nearly constant head that is higher than the natural river elevation.

The aquifer along the Ohio River is capable in most places of yielding from 100 to more than 500 gpm to individual wells. Near Siloam, Ky., an industrial well 82 feet deep yielded 550 gpm with a drawdown of about 12 feet. In Aberdeen, Ohio, a municipal well 91 feet deep, tapping water from gravel, supplies 700 gpm. In Mason County, W. Va., results of a few aquifer tests indicated that comparable yields could be obtained from the aquifer on the south side of the river. The hydrologic characteristics of the Ohio valley deposits are summarized in table 7.

TABLE 7.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE GUYANDOTTE, BIG SANDY, AND LITTLE SANDY RIVER BASINS

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (^{o}F)
Sand and gravel of alluvium in Ohio River valley	60-100	100-500	60-80	30-40	70-210	5-100	10-50	.1-3.0	150-500	----
Sandstones and conglomerates of Pottsville and Allegheny Formations in south-eastern part of report area	----	100-500	110-400	----	50-400	30-350	10-50	----	----	57
Sandstones and conglomerates of Pottsville and Allegheny Formations in north-western part of report area	----	20-100	----	----	----	----	----	----	----	----
Sandstones of the Conemaugh Formation	----	20-100	----	----	----	----	----	----	----	----

The chemical analyses of ground water from the Ohio River valley alluvium indicate that the dissolved-solids concentrations are usually lower than the recommended limit of 500 mg/l for drinking purposes. However, a number of ground-water samples from Colem, Ky., showed hardness values to be about 200 mg/l, and therefore may require softening. The values of sulfate and chloride are invariably much lower than the recommended limits, and do not pose any water-quality problems. However, at many places iron is present in concentrations greater than the 0.3 mg/l limit recommended by the U.S. Public Health Service for drinking water; and treatment may be desirable.

Ground water is available in only limited quantities from alluvium along the Guyandotte River. The alluvium is fine-grained and generally of much lower permeability than glacial valley-fill deposits north of the Ohio River. Alluvium underlies the narrow strip of level floodplain along the river and also fills the abandoned valley of the extinct Teays River, which is now partially occupied by Mud River. At some places the alluvium comprises only a thin veneer overlying the bedrock, but at other places, as along the lower reaches of the Guyandotte River and in the Teays Valley, the alluvium may be as much as 75 feet thick. The portion below river stage is saturated with ground water of a quality acceptable for most uses. The ground-water yields in these alluvial valleys vary from a few gpm to more than 100 gpm, and the water is used for public, domestic, and farm supplies. The alluvium in the upper reaches of tributary streams is much thinner and may yield only enough ground water for domestic consumption.

The alluvium in the valley of the Big Sandy River consists principally of silty material with an admixture of fine sand, and hence is an adequate source of water only for domestic or other small needs. Lenses of coarse sand and gravel are present in some areas. At Allen City, along Levisa Fork, many test holes penetrated alluvium ranging from 10 to 50 feet in thickness; at one place the alluvium was 102 feet thick. Laboratory tests on this alluvium indicated that it is relatively coarse-grained and has relatively high porosity and permeability. Wells along the lower reaches of Big Sandy River, Levisa Fork, and Tug Fork yield as much as 25 to 30 gpm. The alluvium in the small tributary valleys is very thin and cannot be considered as a source of supply for industrial or municipal uses. These deposits, however, are capable of supplying domestic needs.

Test holes drilled along the Little Sandy River and Tygarts Creek penetrated from 3 to 66 feet of alluvium. A test hole drilled at Grayson, Ky., along the Little Sandy River, penetrated 53 feet of saturated alluvium, and one 6 miles west of Greenup penetrated 41 feet of saturated alluvium.

The material encountered in these valleys consists mostly of silt and clay with a varying percentage of fine and very fine sand. At one or two test hole sites, thin beds of gravel interbedded in a matrix of clay were encountered. The ground-water supplies in these valleys are very small and are limited to domestic needs.

There is very little data available on the quality of ground water in the alluvium of the tributary valleys. The available information, however, indicates that ground water is of a mineral quality similar to that in the Ohio River alluvium, and that the values of total dissolved solids are much lower than the recommended limits. In some of the ground-water samples, iron concentrations were found to be much in excess of 0.3 mg/l, and therefore the water may require treatment.

Bedrock Formations

The bedrock formations in the report area consist largely of the Pottsville, Allegheny, Monongahela, and Conemaugh Formations of Pennsylvanian age (plate 16). In the northwest part of the report area there are rock exposures of Mississippian, Devonian, Silurian, and Ordovician age. The southwestern part of the Big Sandy basin is marked by the presence of a thrust-faulted area underlain mostly by rocks of Mississippian and Devonian age.

In regard to areal extent and ground-water yields, the most important bedrock formations in the basin are the Pottsville and Allegheny. The two formations are lithologically and hydrologically similar and therefore are treated herein as a single unit. In Kentucky, these two formations cover most of the Eastern Coal Field region, and vary in thickness from about 700 feet in the northeast to more than 2,500 feet in the south; they consist largely of sandstones interbedded with thin layers of shale, siltstone, limestone, and coal. Water from these sandstones is obtained principally from fractured zones and secondary openings. The ground-water yield from shallow domestic wells is reported to be less than 10 gpm, but deeper wells up to 300 feet or more yield fresh water from 100 to 300 gpm. The water is usually low in dissolved-solids content but has a high concentration of sulfate and iron, and thus may require treatment (see table 7). At Pikeville, an industrial well 120 feet deep supplies 150 gpm of fresh water. Wells deeper than 400 feet usually yield saline water. In some cases in the northern part of the area, saline water has been encountered 100 feet below the principal stream bottoms.

The Pottsville and Allegheny Formations in West Virginia have a thickness varying from 750 to 3,850 feet, and consist primarily of gray and brown coarse-grained sandstone interbedded with thin layers of shale, siltstone, limestone, and coal, and with localized conglomerate beds. The available data indicate that these formations in McDowell, Wyoming, Logan, and Mingo Counties provide the most favorable potential source of ground water. The reported yield of fresh water from wells varying in depth from 100 to 400 feet is generally 100 to 300 gpm. Little data are available regarding the quality of this water, but it generally is rather high in iron and occasionally in sulfate. Sulfate in many of the analyses approaches the limit of 250 mg/l set by the U.S. Public Health Service, and in a few analyses it exceeded the limit. At Tams, a public supply well 250 feet deep yielded 300 gpm. At Iaeger, in McDowell County, another public supply well 200 feet deep yielded 500 gpm. Though the yield may increase at greater depths, the ground water is more mineralized and has high contents of chloride and iron. At some places, saline water may be encountered at depths below 200 feet.

The Pottsville and Allegheny Formations in the southern half of the report area are traversed by the Guyandotte River, Tug Fork, and Levisa Fork. The relatively high dry-weather flows for the upper Guyandotte River and Tug Fork (.068 and .074 cfs per square mile, respectively) indicate that the Pottsville and Allegheny Formations are discharging considerable ground water to these streams, and are a potential source of water to wells. Dry-weather flows for Levisa Fork and its tributaries, the Big Sandy and Little Sandy Rivers, and Tygarts Creek have a lower range of 0.013 to 0.051 cfs per square mile. This may be due to thick, impermeable shale beds within the Pottsville and Allegheny Formations at or near the surface in the drainage areas of these streams. Further study is needed concerning the effects of the geology on streamflow characteristics in this area.

Along the Kentucky-Virginia State line, from near Russell Fork southwest to the boundary of the Big Sandy basin, Mississippian and Devonian rocks have been thrust faulted (the Pine Mountain Thrust Fault) to the surface in a narrow band. The Mississippian and Devonian rocks are mainly limestones. Possible high yields are indicated by records of wells in and near the Breaks Interstate Park along Russell Fork and by data from Pineville, Ky., in an area of apparently similar geologic and hydrologic conditions in the Cumerland basin. Yields of 500 gpm were obtained from Mississippian rocks by two municipal wells at Pineville, 105 and 110 feet deep.

The Conemaugh and the Monongahela Formations are next in order of ground-water yield, and occupy the northeastern part of the basin. These formations consist mainly of varicolored sandy shales and green and brown sandstones with interbedded claystone, coal, and limestone. The thickness of the Monongahela Formation is from 250 to 350 feet. The Conemaugh Formation varies in thickness from 450 to 500 feet. Most of the wells in the Monongahela Formation supply fresh water only for domestic needs, and the yields may not be more than a fraction of a gallon per minute. However, at some places the formation may yield fresh water as much as 10 to 50 gpm. The Conemaugh Formation, at many places in its lower parts, has more permeable sandstone which typically yields 20 to 100 gpm. Wells drilled deeper than about 200 feet, in both the Conemaugh and Monongahela Formations, will yield more water, but the water would be saline in most cases.

Formations of the Mississippian and Devonian Systems in the northwest part of the report area consist mainly of shales, limestones, and occasional thin beds of sandstone. Little data are available concerning their thickness and yields, but their reported yields are not more than a fraction of a gallon per minute, barely enough for domestic needs. The Silurian and Ordovician rocks, mostly shale and limestone, occupy very little space in the report area.

The dry-weather flow of Mud River, where it crosses the Monongahela Formation in its lower reaches, is very low (0.009 cfs per square mile) and indicates that the formation is a poor aquifer. There are not sufficient data available concerning the dry-weather flow of the lower Big Sandy River to indicate the hydraulic characteristics of the Conemaugh Formation, nor for Kinniconick and Salt Lick Creeks to indicate the water-yielding characteristics of the rocks in the Mississippian, Devonian, and Silurian Systems in the northwestern part of the report area.

CURRENT STATUS OF GROUND-WATER INFORMATION

Most of the report area is covered by generalized hydrologic reconnaissance-type reports. A report summarizing available data on the water resources of West Virginia contained information valuable in the interpretation of ground-water resources in the West Virginia part of the report area. The area in Kentucky is covered by ground-water reconnaissance reports and ground-water availability maps for the Eastern Coal Field Region. The area in Virginia is covered by summary reports of ground-water conditions contained in each county report of the "Economic Data Summaries" published by the Virginia Division of Industrial Development and Planning. Ground water in the glacial and alluvial sediments along the south side of the Ohio River is covered in detail by one report for the West Virginia section and by a series of Hydrologic Atlases for the Kentucky section. The Ohio portion of the valley is covered in a series of Ohio Water Plan Inventory maps. Data concerning the hydrologic characteristics of the alluvial deposits in the major tributary valleys of the report area, however, are completely inadequate for even general planning purposes.

The greatest need is for additional information on ground-water quality, including data concerning the increase of dissolved solids concentrations with depth, particularly in the northern part of the report area. Data are also needed regarding iron concentrations throughout the report area, and the effects on water quality of present and past coal-mining and oil-production activities. The Federal Water Pollution Control Administration has made provisions for further study of the ground-water quality situation as part of their coordinated investigations on water resources.

Bibliographic citations for the chief published reports on ground-water availability for areas of county-size or larger are as follows:

Carlston, C.W., and Graeff, G.D., Jr., 1955, Ground-water resources of the Ohio River Valley in West Virginia: West Virginia Geol. Survey, Vol. XXII, part III, 131 p.

Doll, W.L., Meyer, Gerald, and Archer, R.J., 1963, Water resources of West Virginia: West Virginia Div. Water Resources, 134 p.

Hendrickson, G.E., 1958, Summary of occurrence of ground water in Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-10.

Kirkpatrick, G.A., Price, W.E., Jr., and Madison, R.A., 1963, Water resources of eastern Kentucky--progress report: Kentucky Geol. Survey, Ser. X, Rept. Inv. 5, 67 p., 10 pls.

Chio Division of Water, 1959-60, Ohio water plan inventory, Underground water resources: Ohio Dept. Natural Resources, Inv. maps C, N, and M.

Price, W.E., Jr., 1963, Geology and hydrology of alluvial deposits along the Ohio River between South Portsmouth and the Manchester Islands, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-73.

______ 1964, Geology and hydrology of alluvial deposits along the Ohio River between Catlettsburg and South Portsmouth, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-75.

Price, W.E., Jr., Kilburn, Chabot, and Mull, D.S., 1962, Availability of ground water in Breathitt, Floyd, Harlan, Knott, Letcher, Martin, Magoffin, Perry, and Pike Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-36.

______ 1962, Availability of ground water in Boyd, Carter, Elliott, Greenup, Johnson, Lawrence, Lee, Menifee, Morgan, and Wolfe Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-37.

Price, W.E., Jr., Mull, D.S., and Kilburn, Chabot, 1962, Reconnaissance of ground-water resources in the Eastern Coal Field Region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1607, 56 p. 9 pls.

Walker, E.H., 1957, The deep channel and alluvial deposits of the Ohio Valley in Kentucky: U.S. Geol. Survey Water-Supply Paper 1411, 24 p., 6 pls.

MANAGEMENT CONSIDERATIONS

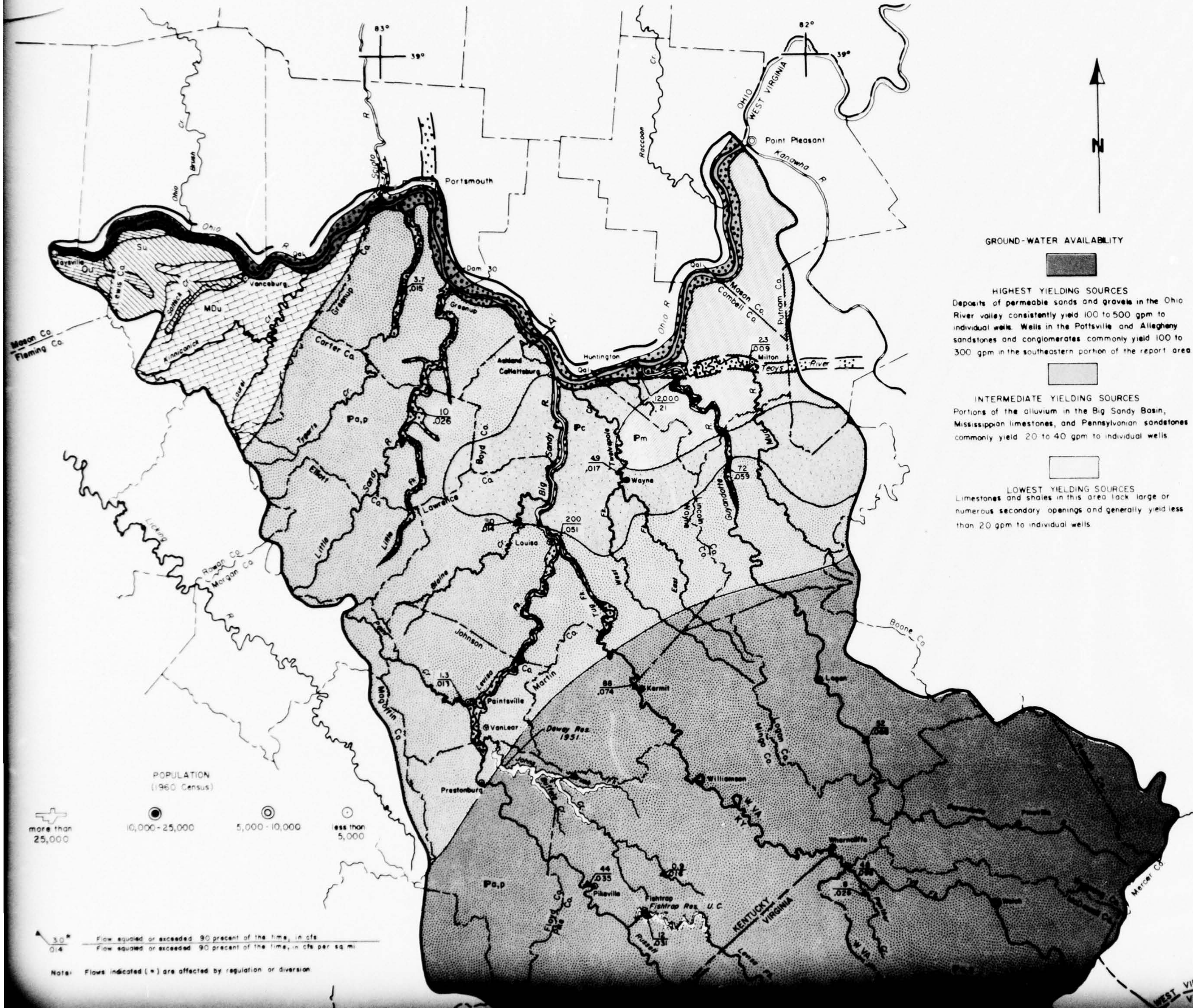
Very large-scale future water developments are feasible along both sides of the Ohio River between Pt. Pleasant and Maysville. The water-supply potential is greatly enhanced by construction of the Gallipolis and Greenup locks and dams. The hydrologic effects of these navigation facilities on the water-supply capability of the unconsolidated valley fill and terrace deposits in terms of increased ground-water storage, higher heads, and recharge rates will generally be beneficial and should be studied in detail as a planning guide to future facilities. The effects of sediment transport and deposition on recharge rates, and of recharge on water quality, also need to be studied in detail prior to large-scale development of the alluvium. In addition, the beneficial effects on agriculture, such as reduced lifts for irrigators, as well as detrimental effects, such as water logging, need to be studied.

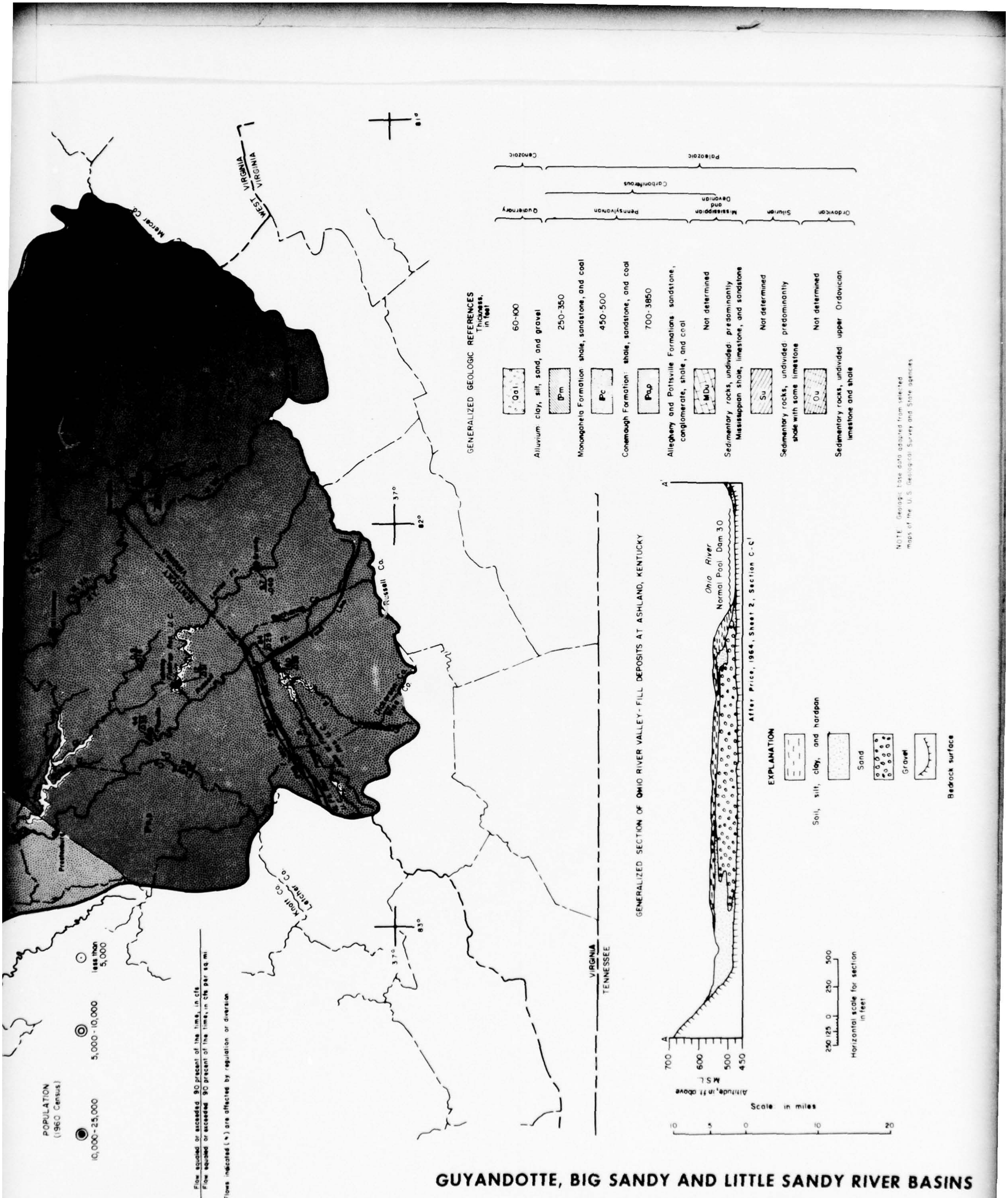
In the drainage areas of the Ohio River tributaries within the report area, large-scale water developments in the foreseeable future will probably rely mainly on the continued construction of surface reservoirs, although some ground-water sources can adequately fill municipal and industrial needs. This is especially true in the upper Guyandotte and Big Sandy basins where the Pottsville and Allegheny Formations can be tapped for water supplies. The development of ground water in this area is especially desirable because its quality is generally unaffected by coal-mining activities, whereas some of the surface streams contain acid waters discharging from the numerous coal mines in the area.

In most parts of the upper Guyandotte and Big Sandy basins, iron must be removed from the ground water to make it suitable for use. However, chemical quality data on which to assess the problems that might arise from large-scale ground-water development are inadequate. At the present time there is little demand for water development in this area, so the nature of problems that might arise cannot be accurately predicted. Future areal studies should await plans for specific developments as they arise. Water development in the report area might not be long in coming, due to the interest of governmental and private agencies in furthering the economic recovery of the Appalachian Region.

Some of the towns and villages in the report area obtain their water supplies from coal mines which serve as artificial collectors of percolating ground water. As economic development of such places progresses, investigation of such sources of supply should be made to determine their adequacy for future needs and the suitability of their water quality. Also, the life expectancy of the mines should be determined in terms of possible cave-ins or other factors that might impair the water quality or reduce the quantities discharged.

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY





GUYANDOTTE, BIG SANDY AND LITTLE SANDY RIVER BASINS
SOURCES OF GROUND WATER

PLATE 16

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 8

GREAT MIAMI AND LITTLE MIAMI
RIVER BASINS
(Including northside drainage area to the Ohio River
between Maysville and Madison)

By

Andrew M. Spieker

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

GREAT MIAMI AND LITTLE MIAMI RIVER BASINS

CONCLUSIONS

The report area has among the highest, if not the highest, ground-water yields of the Ohio River basin. The best sources of ground water are the Great Miami valley-fill deposits, which are conveniently located with respect to the points of greatest need--the Cincinnati metropolitan area and the industrial-metropolitan complexes of the lower Great Miami River valley.

The chief sources of ground water, in order of estimated decreasing potential, are as follows:

1. Sand and gravel deposits in the lower Great Miami and the Mad River valleys.
2. Sand and gravel deposits along the entire course of the Whitewater River valley.
3. Sand and gravel deposits in the upper Little Miami River valley.
4. Sand and gravel overlain by clay in abandoned pre-glacial valleys.
5. Limestones and dolomites of the Silurian System in the north, east, and west parts of the report area.
6. Sand and gravel lenses within the glacial drift in much of the northern part of the report area.
7. Limestones of the Devonian System in the northeastern corner of the report area.

The ground-water resources of the report area are adequate to meet very large industrial and municipal needs. This great potential can be increased to fill foreseeable needs if modern management techniques such as interbasin transfer of water and artificial recharge are employed.

Despite the apparent potential for development of water supplies from strata of the Silurian System, such development will follow that of the more-productive overlying glacial drift and surface-water sources.

PHYSIOGRAPHY AND DRAINAGE

The present report covers the land draining from the north to the Ohio River between Maysville and Madison, and includes the drainage basins of Eagle and Whiteoak Creeks, the Little Miami River, Mill Creek, the Great Miami River, the Whitewater River, Laughery and Indian Creeks in Ohio and Indiana. The valley-fill deposits of the Ohio River are described in the following section covering ground-water conditions in the Licking and Kentucky River basins. The report area lies almost entirely in the Till Plains Section of the Central Lowlands Physiographic Province. The extreme southeastern corner of the area, in the lower part of the Eagle Creek basin, however, is in the unglaciated Bluegrass Region of the Interior Low Plateau. Topography of the Till Plains is characterized by flat to gently rolling terrain, with the most pronounced relief caused by glacial moraines in the northern parts of the report area, and by dissected bedrock topography in the southern part. The valleys of many of the major streams have been cut to levels as much as 200 feet below the till plain.

The north edge of the Ohio River, which forms the southern boundary of the report area, also marks the approximate southern boundary of continental glaciation. Topography of the southern part of the report area, comprising the terrain south of approximately Hamilton, Ohio, is transitional between the characteristic glaciated and unglaciated topographies.

Most of the report area northeast of Cincinnati is in the drainage basin of the Little Miami River, which rises in the glaciated area southeast of Springfield and flows past Xenia, Morrow, and Milford, to its confluence with the Ohio River east of Cincinnati. Its principal tributaries are Caesar Creek, Todd Fork, and East Fork. The main tributaries east of the Little Miami River basin are Whiteoak, Straight, and Eagle Creeks.

A large part of the Cincinnati metropolitan area between the Little Miami and Great Miami basins is drained by Mill Creek. West of the Great Miami-Whitewater basin, the principal tributaries are Hogan, Laughery, and Indian Creeks.

The drainage area of the Great Miami River basin is generally separated into two parts: the Great Miami River basin, and the Whitewater River basin. The Whitewater basin can virtually be regarded as separate from the Great Miami, inasmuch as the Whitewater River enters the Great Miami River only six miles above its mouth. The drainage divide between the Great Miami and Whitewater basins approximately follows the Ohio-Indiana State line.

The Great Miami River has its source at Indian Lake in Logan County, Ohio, from where it flows past Sidney, Piqua, and Troy, to Dayton, where it is joined by its two principal tributaries, the Stillwater and Mad Rivers. Together, these three streams comprise the upper Great Miami River basin. The lower Great Miami River flows from Dayton past Middletown and Hamilton to its confluence with the Ohio River at the Ohio-Indiana State line.

The Whitewater River has its source in several forks, which rise in and near Randolph County, Indiana. These forks join near Connersville, from where the Whitewater continues its course southeast, to the confluence with the Great Miami. The remainder of the report area is drained by several minor tributaries to the Ohio River in Indiana, including Hogan, Laughery, and Indian Creeks.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

Nearly all of the report area is covered with glacial drift ranging in thickness from a few feet to 300 feet. Outwash deposited in the major stream valleys makes up most of the area's best sources of ground water. In contrast, lake deposits, especially those in southeastern Indiana, consist generally of the fine-grained materials--silt and clay--and are not good sources of ground water. The till deposits that cover much of the report area are not good sources of ground water.

Most of the area's large municipal and industrial ground-water supplies are developed in glacial outwash deposits, which are found generally underlying the courses of the principal streams. Outwash also occurs as extensive outwash plain deposits, such as those in the Mad River valley north of Springfield and in the Whitewater River valley near Connersville. Ground water discharging from these highly permeable deposits sustains the dry-weather flow of most of the area's major rivers. Whiteoak Creek, near Georgetown, has a low-flow index of only .012 cfs per square mile, reflecting the absence of permeable outwash deposits in the drainage area. West Fork Whitewater River near Connersville, on the other hand, has a low-flow index of .14, which is fairly typical for streams whose drainage areas are underlain by permeable glacial outwash deposits. The low-flow indexes at the area's principal gaging stations are shown on plate 17.

Virtually no outwash deposits are present in the basins of the minor tributaries east of the Little Miami River basin. In most of this part of the area, bedrock is overlain by a thin mantle of Illinoian till, generally less than 25 feet thick. The previously cited low-flow index of Whiteoak Creek near Georgetown can be considered as representative for these small basins. The unconsolidated deposits in this part of the area generally lack sufficient permeability or thickness to sustain even small domestic wells.

The upper part of the Little Miami River valley is underlain by fairly extensive outwash deposits, as indicated by the large low-flow index of .14 cfs per square mile of the Little Miami River at Spring Valley. These sand and gravel deposits range in thickness from 100 to 200 feet (table 8). Yields of individual large-diameter wells are commonly 500 to 1,000 gpm, with some wells yielding as much as 2,000 gpm. The city of Xenia depends on wells drilled into these outwash deposits for its municipal water supply. Most of the capacity of these extensive deposits, however, remains unused.

TABLE 8.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE GREAT MIAMI AND LITTLE MIAMI RIVER BASINS.

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (°F)
Unconsolidated Sediments										
Glacial outwash sand and gravel along major streams	20-250	500-3,000	40-200	5-40	300-550	30-120	5-30	0-4.0	300-650	40-75*
Glacial outwash sand and gravel overlain by till deposits	10-50	100-1,000	50-150	5-100	300-550	30-120	5-30	0.5-4.0	300-650	52-56
Thin beds of sand and gravel in moraines and till plains	2-10	0-50	50-100	5-50	300-550	30-120	5-30	0.5-4.0	300-650	52-56
Bedrock Formations										
Limestones and dolomites of the Silurian System	----	10-50	100-200	5-60	300-600	40-150	10-60	2.0-10	350-700	52-56
Shales of the Ordovician System	----	0-10	100-200	5-60	300-600	40-150	10-60	0.5-5	350-700	52-56

*Temperatures below 52° and above 56°F influenced by induced stream infiltration.

Outwash sands and gravels are scarce in the lower Little Miami River basin, except for a few small patches in the reach between Loveland and Milford. The low-flow index of the Little Miami River at Milford is .078 cfs per square mile, reflecting the increase in drainage area over the upstream station at Spring Valley without a corresponding increase in ground-water contribution to the base flow.

The basin of Mill Creek contains much of the Cincinnati metropolitan area. The Mill Creek valley, nearly two miles wide, follows the course of the ancestral Ohio River, which prior to the Illinoian glaciation flowed northwest through Norwood toward Hamilton, from which it followed essentially the present course of the Great Miami River, rejoining the present course of the Ohio River near Lawrenceburg, Ind. The trough of this ancient valley was subsequently filled with outwash and lake clay. In general, the sand and gravel aquifer in the Mill Creek valley is 75 to 100 feet thick and is overlain by about 100 feet of relatively impermeable lake deposits. These clay and silt deposits impede recharge from the stream to the underlying permeable outwash deposits. Mill Creek at Carthage has a low-flow index of .004 cfs per square mile, indicating the poor hydraulic connection between the stream and outwash deposits.

Much of Cincinnati's industry is located in the Mill Creek valley. Therefore the valley-fill aquifer has long been heavily pumped for industrial water supplies. Recharge to this aquifer in the industrialized area has been estimated to be about 8.5 mgd. Total pumpage, however, has for many years ranged from 10 to 13 mgd, resulting in a perennial overdraft of this aquifer and declining ground-water levels.

The most extensive glacial outwash aquifers in the report area are in the Great Miami-Whitewater River basin. Considering first the Great Miami portion of this basin, outwash deposits underlie nearly the entire course of the Great Miami River south of Dayton, and nearly all of the course of the Mad River, the Great Miami's principal tributary northeast of Dayton. Outwash deposits are of much smaller areal extent in the upper part of the Great Miami River valley, north of Dayton. These outwash deposits range in thickness from 100 to 250 feet in the main valleys, and are generally less than 100 feet thick in the tributary valleys. Large ground-water supplies in these very permeable valley-fill deposits are sustained by induced infiltration from the area's major streams. Individual wells sufficiently near a stream to be recharged by induced infiltration can yield as much as 3,000 gpm. Wells not receiving induced recharge from streams can be expected to yield 500 to 1,000 gpm.

The Mad River has the largest low-flow index of any stream in the Ohio River basin, with the exception of some streams in mountainous areas where precipitation is considerably greater than in the flatlands. Mad River, near Springfield, for example, has a 90 percent duration discharge of .31 cfs per square mile, the highest for any stream gaged in Ohio. Other stations in this basin have similarly high dry-weather flow indexes.

Ground-water development in the Great Miami River valley is the most extensive of any area in Ohio. Total pumpage from Dayton to the Ohio River averages more than 200 mgd, most of which is concentrated at Dayton, Miamisburg, Middletown, and Hamilton. All these cities depend entirely on ground water for their municipal water supplies. The largest single municipal water supply in the area is that of Dayton, whose average pumpage is 46.6 mgd. The Dayton municipal water supply is the largest in the Midwest and the seventh largest in the United States wholly dependent on ground water.

North of Middletown, areally extensive interstratified clay layers are generally present in the valley fill, necessitating careful well construction and development techniques. Such clay layers are generally not present south of Middletown. In either environment, individual properly constructed wells can yield in excess of 3,000 gpm. Although ground-water development around the major cities is extensive, vast areas of the valley fill remain untapped. The valley-fill aquifers of the Great Miami River basin are believed capable of producing much more water than is being pumped at present.

The western part of the Great Miami-Whitewater River basin, mostly in Indiana, is drained by the Whitewater River and its tributaries. Like the Great Miami, the Whitewater River is underlain by extensive glacial outwash deposits. South of Harrison these deposits are 100 to 150 feet thick, while north of Harrison their thickness is typically from 50 to 75 feet. Although these deposits appear to be more extensive than the Mad River outwash deposits in Ohio, the low-flow index of the Whitewater River is not nearly as large as that of the Mad River. The discharge of Whitewater River at Brookville equaled or exceeded 90 percent of the time is .12 cfs per square mile, which is a characteristic value for a stream underlain by permeable gravel deposits, but still well below the values in the Mad River valley. The difference can be attributed to the greater thickness and perhaps the greater permeability of the Mad River deposits.

No extensive outwash deposits are found in the minor tributary valleys in the report area west of the Whitewater River basin. Laughery Creek, for example, is largely underlain by lake deposits of low permeability. The gaging station on Laughery Creek near Farmer's Retreat has a low-flow index of .002 cfs per square mile, the smallest in the report area.

Glacial outwash deposits about 100 feet thick, overlain by 50 to 100 feet of clay, are sources of ground water in four areas along former courses of the Great Miami and Ohio Rivers and at least one principal tributary. These areas are situated northwest of Middletown, southeast of Middletown, southeast of Hamilton, and between Ross and Harrison. Individual wells drilled into the gravel through the clay in these areas can yield as much as 500 gpm; some yields of more than 1,000 gpm have been reported.

Those parts of the area not underlain by outwash deposits or lake clays are underlain by till-plain and morainal deposits. These deposits generally consist of till, a hard and tight clay matrix containing pebbles, cobbles, and boulders. The till ranges in thickness from zero to more than 100 feet; at some locations bedrock protrudes through thinner parts of the till plain. Till is generally thicker and more heterogeneous in the moraines, which locally may contain lenses of sand and gravel that can be tapped for small water supplies.

Till is generally a poor source of ground water. Many farms and homes on the till plain are forced to rely on dug wells, whose large storage capacities provide barely adequate supplies. Scattered pockets and lenses of sand and gravel in the till, however, can provide more dependable sources of supply, but their distribution is unpredictable. East of Piqua is an area where extensive gravel lenses in the till are known to exist. Yields of as much as 100 gpm have been reported from these deposits. These deposits, whose areal extent is not fully known, are more extensive than the more typical gravel lenses in till.

The valley of the pre-glacial Teays River crosses the northeastern part of the report area, as shown on plate 17. This 300-foot deep valley is believed to be filled largely with silt and clay and hence is not a good source of ground water.

Ground water from the glacial deposits is generally of the calcium bicarbonate type, characteristically rather hard. The total dissolved solids content typically ranges from 350 to 650 mg/l. Water from some wells, particularly those penetrating till or clay, has a high iron content, sometimes as high as 5 mg/l.

Bedrock Formations

Bedrock aquifers are at best a secondary source of ground water in the report area. Owing to the abundance of ground water in the glacial outwash deposits, the area's bedrock aquifers have not been extensively developed.

The area of the present report lies on the crest of the Cincinnati Arch, a broad and gentle flexure that stands out prominently on a geologic map of the United States. At the crest of the arch are the shales with thin interbedded limestones of the Cincinnatian Series of Late Ordovician age. These shales are overlain by limestones and dolomites of the Clinton shale and Niagara Group of Silurian age. Owing to the structure of the arch, the Cincinnatian shales crop out in the southern and central parts of the area (pl. 18), and are ringed to the north, east, and west by the Silurian rocks. Strata on the east flank of the Cincinnati Arch dip eastward about 20 feet per mile, while the average dip of strata on the arch's west flank is about 10 feet per mile. Strata are virtually flat-lying on the crest of the arch, which makes up most of the central part of the report area. A small patch of the Columbus Limestone and Ohio Shale, part of the Bellefontaine Outlier, crops out in the northeastern corner of the report area.

While both the Ordovician and the Silurian strata have been subdivided into smaller stratigraphic units, to a large extent on the basis of fossils, from a hydrogeological standpoint only the major bedrock systems need be described herein. Small to moderate ground-water supplies of from 10 to 50 gpm can generally be developed in the Silurian limestones and dolomites, which are from 200 to 350 feet thick. These occur in the northern part of the area and on its eastern and western flanks. The Devonian rocks near Bellefontaine have similar water-yielding characteristics. A few bedrock wells yielding in excess of 100 gpm have been reported in the Springfield area. The bedrock aquifers have never been extensively developed for large ground-water supplies owing to the greater abundance of water in the unconsolidated deposits. It is quite possible that further study of the bedrock aquifers would reveal that moderately large ground-water supplies are generally available. The limestone and dolomite aquifers are generally adequate as sources for domestic and rural water supplies.

Shales of the Cincinnatian Series of Late Ordovician age, ranging in thickness from 750 to 1,000 feet, are relatively impermeable and cannot generally be considered a source adequate for even small domestic supplies. Many wells drilled into these rocks are failures, while some yield 1 to

5 gpm, barely adequate for domestic or rural supplies. Weathering has produced secondary permeability in some small areas where the shale crops out in depressions. A few domestic supplies have been developed at such locations.

Fresh water generally does not occur at depths in excess of 500 feet beneath the surface. Some wells in the Cincinnati area have tapped the "Blue Lick zone", near the base of the Ordovician System, from which salt water has been pumped for industrial cooling purposes. This zone occurs at an altitude of about 410 feet below sea level, or 850 feet below the Ohio River at Cincinnati.

The chemical quality of water from the consolidated rock formations in the report area is similar to that of water from the unconsolidated deposits, except that, as a rule, the iron content of water from rock wells is high, whereas many wells in the unconsolidated sediments yield water relatively low in iron.

CURRENT STATUS OF GROUND-WATER INFORMATION

Reconnaissance maps of ground-water availability have been published by the Ohio Division of Water (1958) for the entire state. A somewhat more detailed report covering the geologic occurrence of ground water in Ohio was published by the Ohio Geological Survey (Stout and others, 1943). Detailed reports on the geology of Clark, Greene, Montgomery, Butler, and Hamilton Counties, Ohio, have been prepared by the U.S. Geological Survey in cooperation with the Ohio Water Resources Board and the Ohio Division of Water. Detailed quantitative reports have been prepared on the occurrence of ground water in the Dayton, Ross, and Fairfield-New Baltimore areas, Ohio, by the U.S. Geological Survey, in cooperation with the Ohio Division of Water and the Miami Conservancy District. The Division of Geology of the Indiana Department of Conservation prepared a report covering the geology of ground water in all of Indiana (Harrell, 1935).

Following are bibliographic references for the more important publications on ground water in the report area:

Bernhagen, R.J., and Schaefer, E.J., 1947, Ground-water conditions in Butler and Hamilton Counties, Ohio, 1946: Ohio Water Resources Bd. Bull. 8, 35 p., 13 pls.

Dove, G.D., 1961, A hydrologic study of the valley-fill deposits in the Venice area, Ohio: Ohio Div. Water Tech. Rept. 4, 82 p.

Harrell, Marshall, 1935, Ground water in Indiana: Indiana Dept. Cons. Div. Geology Publ. 133, 504 p.

Indiana Water Resources Study Committee, 1956, Indiana water resources: Indiana Flood Control and Water Resources Comm. Rept. and Tech. Appendix.

Klaer, F.H., Jr., and Thompson, D.G., 1948, Ground-water resources of the Cincinnati area, Butler and Hamilton Counties, Ohio: U.S. Geol. Survey Water-Supply Paper 999, 168 p., 15 pls., 22 figs.

Norris, S.E., Cross, W.P., and Goldthwait, R.P., 1948, The water resources of Montgomery County, Ohio: Ohio Dept. Nat. Resources Div. Water Bull. 12, 83 p., 48 pls.

_____ 1950, The water resources of Greene County, Ohio: Ohio Dept. Nat. Resources, Div. Water Bull. 19, 52 p., 23 pls.

Norris, S.E., Cross, W.P., Goldthwait, R.P., and Sanderson, E.E., 1952, The water resources of Clark County, Ohio: Ohio Dept. Nat. Resources, Div. Water Bull. 22, 82 p., 29 pls., 18 tables.

Norris, S.E., and Spieker, A.M., ____, Ground-water resources of the Dayton area, Ohio: U.S. Geol. Survey Water-Supply Paper 1808, in press.

Ohio Division of Water, 1958, Ohio water plan inventory project: Ohio Div. Water, Underground Water Resources Maps H 1-11; J; K 1-6; L 1-3.

______ 1960, Water inventory of the Ohio Brush, Eagle, Straight, and Whiteoak Creek Basins: Ohio Div. Water Rept. 15.

______ 1964, Water inventory of the Little Miami and Mill Creek Basins, and adjacent Ohio River tributaries: Ohio Div. Water Rept. 18.

Spieker, A.M., 1961, A guide to the hydrogeology of the Mill Creek and Miami River valleys, Ohio: Geol. Soc. America Guidebook Series, Cincinnati Meetings, 1961, p. 217-251.

______ 1964, Effect of increased pumping of ground water in the Fairfield-New Baltimore area, Ohio: A prediction by analog model study: U.S. Geol. Survey Open-File Rept., 100 p.

Stout, Wilber, Ver Steeg, Karl, and Lamb, G.F., 1943, Geology of water in Ohio: Ohio Geol. Survey Bull. 44, 694 p., 8 maps, table.

Information in the above-cited reports, as summarized in the present report, indicates that abundant ground-water supplies are available in the glacial outwash deposits that cover much of the area. Adequate geologic information is available for much of the area in Ohio, and quantitative information is available for a few parts of the Great Miami River valley. More detailed hydrogeologic coverage is needed in the upper Great Miami River basin and in the Little Miami River basin. Better hydrogeologic coverage is needed for the Whitewater River basin in Indiana. Detailed quantitative studies should be made of any specific sites where the development of large ground-water supplies is anticipated. Relatively little is known of the hydrogeology of the consolidated rock deposits. The Silurian limestones and dolomites can be regarded as potential sources of moderate to large ground-water supplies and are therefore deserving of further study.

MANAGEMENT CONSIDERATIONS

The potential for development of large ground-water supplies in the Great Miami-Whitewater and Little Miami River basins is among the greatest in the entire Ohio River basin. The glacial outwash deposits in these basins are capable of yielding many times the amount presently being withdrawn. This high potential is of special importance when one considers the widespread availability of this resource, and especially the availability of ground water at and near the major urban and industrial complexes.

Abundance of ground water does not necessarily imply any lack of problems concerning its development or management. The major existing or potential problems can be classified into three mutually interdependent categories: sustained long-term overdraft of aquifers; conflicts between competing users of the ground-water resources; and possible pollution of ground-water supplies.

Pollution of ground water is not at present a serious problem in the report area. It is, however, a potential problem in those parts of the area, particularly in the lower Great Miami River valley, where large ground-water supplies are sustained by induced stream recharge. Water in the lower Great Miami River is highly polluted, particularly during prolonged periods of low streamflow. Some pollution of the valley-fill aquifers has already occurred, as demonstrated by analyses of ground water containing phenolic compounds and detergents (ABS), substances that do not occur in natural waters. Some wells receiving induced infiltration furthermore have a higher than normal concentration of nitrates. None of these substances is present in dangerous quantities; however, wells containing them should be monitored to forestall any dangers involving the use of contaminated water. A requisite for the continued development of the area's prolific ground-water resource will be a detailed management study of techniques of pollution abatement and quality control.

Although the valley-fill deposits are generally able to sustain large industrial and municipal ground-water supplies, a few areas of chronic overdraft do exist. These problem areas are the result of industrial development in parts of the valley where natural recharge to the aquifer does not meet the industry's water demand. The two most prominent areas of overdraft are in the Great Miami valley southeast of Middletown, and in the Mill Creek valley, where much of Cincinnati's industrial complex is located. A third area of potential overdraft is in the south part of Dayton, where industrial pumpage is on the verge of exceeding the capacity of the Great Miami valley-fill aquifer.

Alternative solutions to the overdraft problem in the Mill Creek valley are increased efficiency in industrial water use and turning to alternate sources of supply. The second alternative could be approached in either of two ways--namely for individual users to import water for their needs or for a program designed to recharge and refill the aquifer, possibly using water diverted to Mill Creek from the Great Miami River. All these approaches have been applied in the report area. The Armco East Works has over the past several years doubled its production capacity without materially increasing water consumption through more efficient use and reuse of water. Extensive reuse of water, on the other hand, may result in deterioration of certain water-quality parameters, as by increasing temperature and dissolved solids content.

Within the area covered by this report, the most important problems confronting ground-water users are the legal and jurisdictional constraints on development of sources of supply for the Cincinnati metropolitan area. At present, the Ohio River meets most of Cincinnati's demands, at least from a quantity standpoint, but quality problems are encountered, especially during low-flow periods. This study indicates that ground water could readily be developed in adequate quantities to provide an alternative source of supply of water of generally better quality for needs in the metropolitan area.

A comprehensive plan for development of the water resources in the Cincinnati area would of necessity consider solutions to the legal and jurisdictional problems as well as the engineering feasibility of developing ground-water sources for alternate supplies.

An example of the constraints on regional ground-water development is afforded by the 1961 proposal of the Cincinnati Water Works to install a well field in the Great Miami River valley west of Fairfield. This proposal met with strong opposition from Butler County and Hamilton interests which had opposed a similar proposal made during World War II. Although a consensus of reports indicates that the aquifer can sustain the proposed withdrawal, local interests have thus far blocked Cincinnati's attempts to start construction of the well field. The matter is pending in Ohio courts.

The Cincinnati metropolitan area is certain to expand, and its expansion is equally certain to bring about increased water demands. Common sense would dictate that the most likely sources of water to be tapped are the valley-fill aquifers of the Great Miami and Whitewater River valleys. Optimum utilization of these sources, however, will require revision of the traditional legal constraints that prevent the removal of water from one drainage basin to another.

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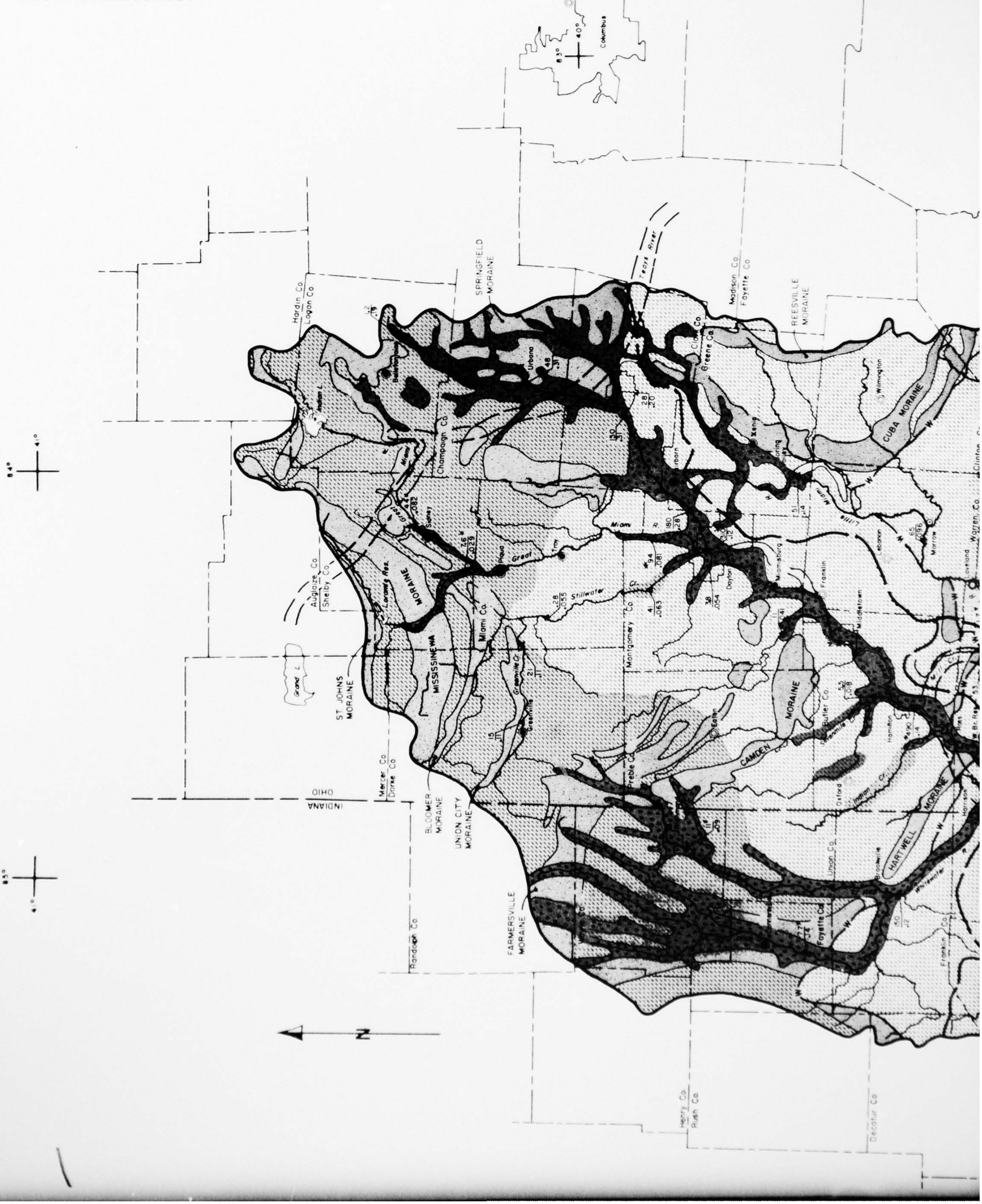

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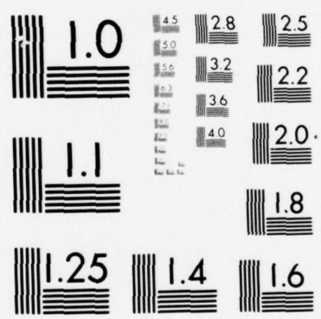

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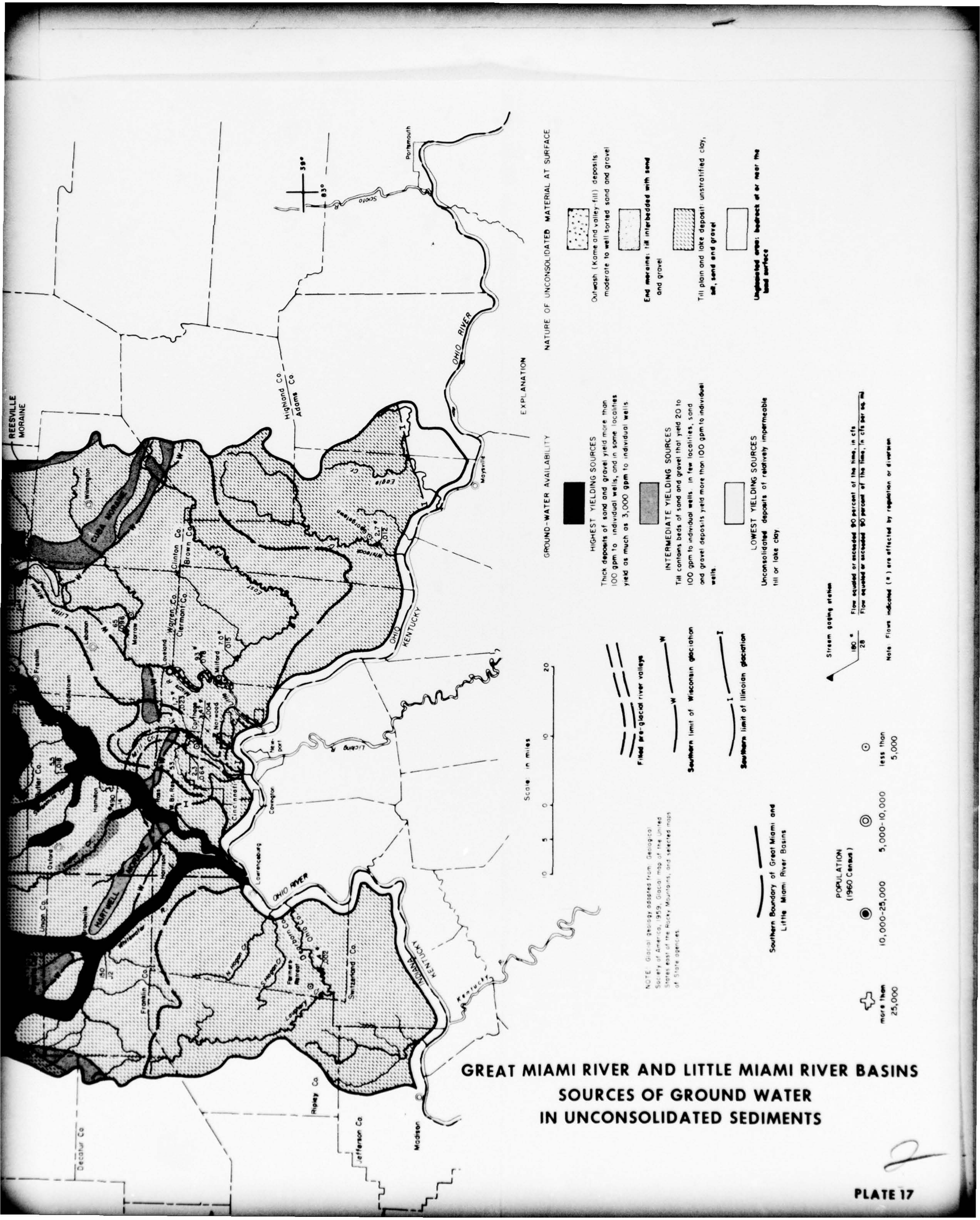

GREAT MIAMI RIVER AND LITTLE MIAMI RIVER BASINS
SOURCES OF GROUND WATER
IN UNCONSOLIDATED SEDIMENTS

PLATE 17

U.S. DEPARTMENT OF THE INTERIOR
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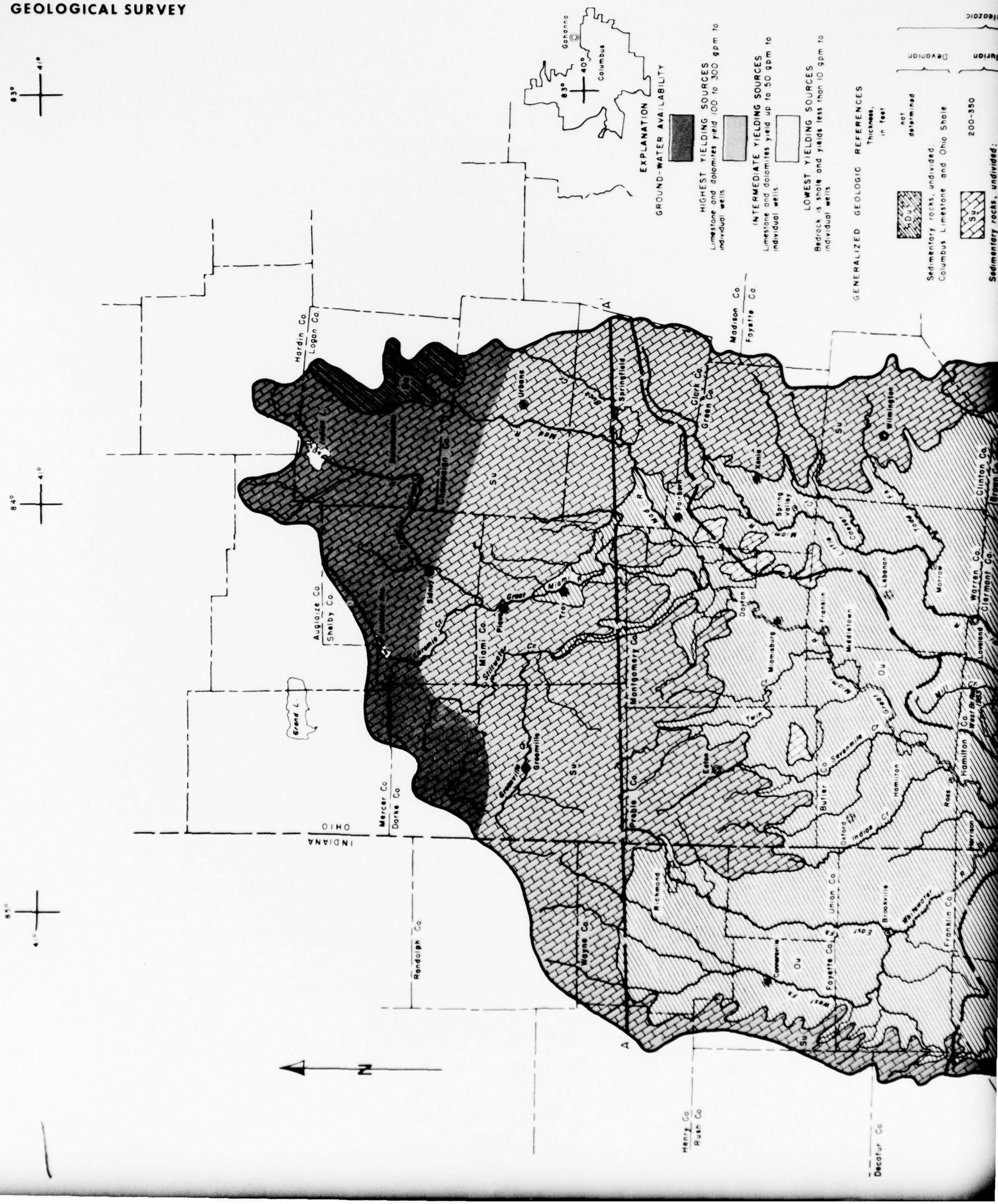

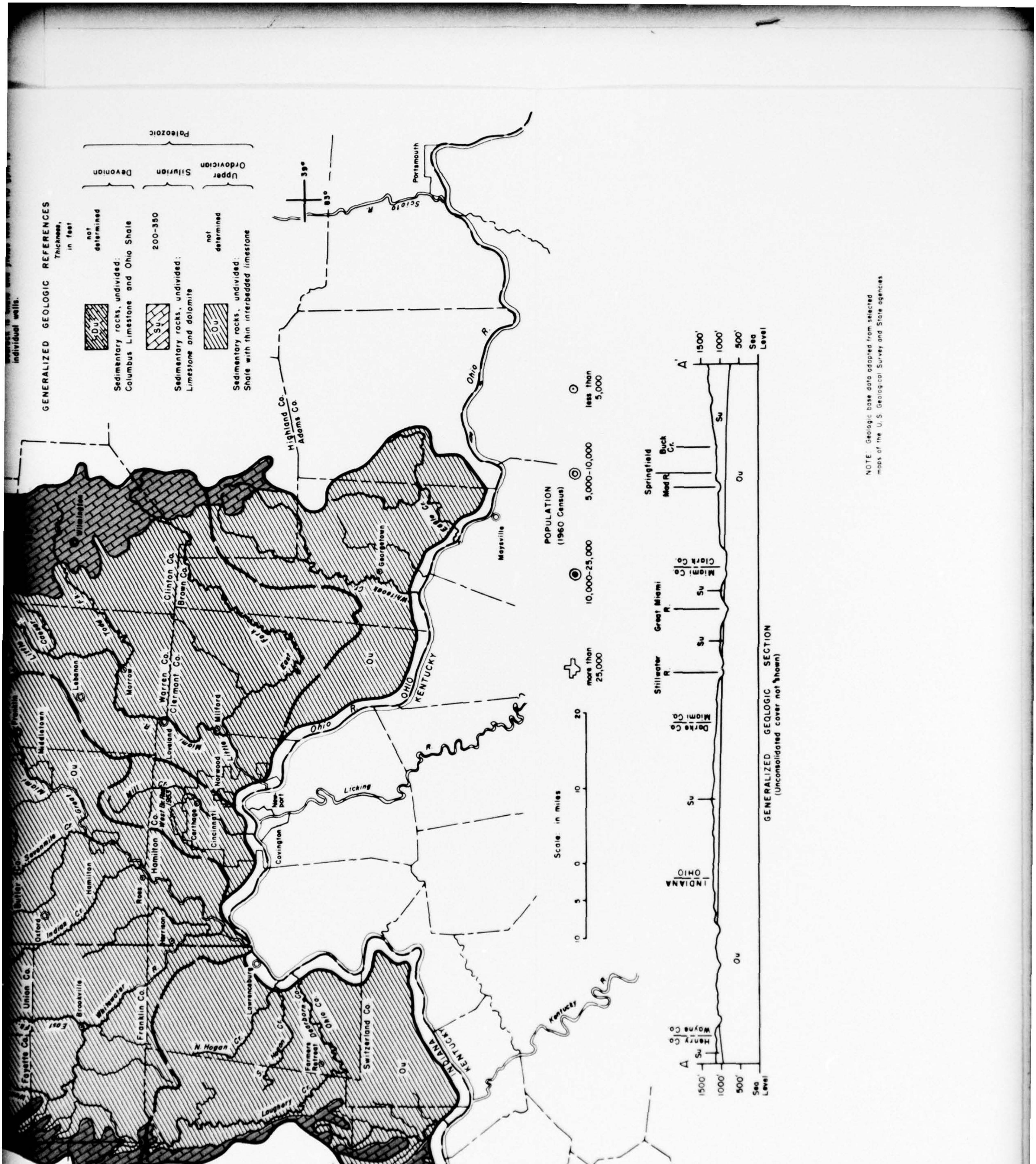

GREAT MIAMI AND LITTLE MIAMI RIVER BASINS
SOURCES OF GROUND WATER
IN BEDROCK FORMATIONS

PLATE 10

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 9

LICKING AND KENTUCKY RIVER BASINS
(Including southside drainage area to the Ohio River and Ohio River alluvium between Maysville and Madison)

By

George D. Dove

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

LICKING AND KENTUCKY RIVER BASINS

CONCLUSIONS

Supplies of ground water in great quantities are available for present and future development from the alluvium along the Ohio River between Maysville, Ky., and Madison, Ind. The wells should be located close to the river because most of the recharge to the underlying alluvial aquifer is from the river and because it has been found that many wells drilled near the valley walls yield water high in mineral content. Individual wells drilled into the unconsolidated deposits along the river range from 80 to 155 feet in depth and yield as much as 1,500 gpm of water.

The alluvium along the Kentucky and Licking Rivers is finer grained than that of the Ohio, but coarse sands and gravels are found in some areas. Adequate domestic yields can generally be obtained in most areas along the rivers, and the more permeable materials yield as much as 300 gpm of water. Wells drilled into the alluvium along the Kentucky River range from 60 to 135 feet in depth, and are about 100 to 150 feet deep along the Licking River.

Consolidated rocks ranging in age from Ordovician to Pennsylvanian are exposed at the land surface in the basins. The most favorable bedrock ground-water areas are the inner Blue Grass region underlain by thick, pure limestones, and the Eastern Coal Field region, where thick sandstones are present. Wells in the inner Blue Grass region range from about 20 to 240 feet in depth and yield from 5 to 400 gpm of water. A few springs in this region reportedly flow at rates of about 450 to 900 gpm. In the Eastern Coal Field region, wells in the thick sandstones, principally the Breathitt and Lee Formations, range from 15 to 600 feet in depth and reportedly yield as much as 600 gpm.

In the outer Blue Grass region, and in parts of the Eastern Coal Field region, wells tapping the upper Ordovician limestones, and the Silurian, Devonian, and Mississippian sandstones and shales range in depth from 20 to 300 feet and yield 1 to 5 gpm of water. One well in the Maysville Group reportedly yielded 100 gpm. The chief sources of ground water, in order of estimated decreasing potential, and their general locations are as follows:

1. Alluvium along the Ohio Valley on both sides of the river, from Maysville to Madison.

2. Limestone aquifers of middle Ordovician age in the inner Blue Grass region.

3. Sandstones of the Breathitt and Lee Formations of Pennsylvanian age.

4. Alluvium along the Kentucky River from Frankfort north to Carrollton, and alluvium along the Licking River from about Falmouth north to Maysville.

5. Interbedded limestones and shales of late Ordovician age in the outer Blue Grass region.

In the Blue Grass region, most of the water from drilled wells is of the calcium bicarbonate type and has a hardness of 250 to 350 mg/l. Water from wells and springs in the Eastern Coal Field region is also of the calcium bicarbonate type, but the hardness is generally lower than that in the Blue Grass region. The two most objectionable constituents in the basins are hydrogen sulfide and sodium chloride. Sodium chloride, salt, occurs in almost all wells over 300 feet deep.

PHYSIOGRAPHY AND DRAINAGE

This report covers the area draining from the south to the Ohio River between Maysville, Ky., and Madison, Ind., including the basins of the Licking and Kentucky Rivers, as well as the alluvium on the north side of the river in Ohio and Indiana. The total drainage area covered is about 12,000 square miles, including about 7,000 square miles for the Kentucky River basin, and 3,700 square miles for the Licking. The length of the reach of the Ohio River between Maysville and Madison is about 150 river miles.

The Licking River and the South, Middle, and North Forks of the Kentucky River all rise in the Kanawha Physiographic Section (Eastern Coal Field region) of the Appalachian Plateau. The South and North Forks join at Beattyville to form the Kentucky River. The Middle Fork joins the North Fork a few miles east of Beattyville. From Beattyville, the Kentucky River continues northward across the Lexington Plain section of the Interior Low Plateau province to Carrollton, where it joins the Ohio River. In Kentucky, the Interior Low Plateau is sub-divided into the Knobs, and Outer and Inner Blue Grass regions. The Licking River rises near the Floyd-Breathitt-Knott County junction, and flows northward across the Lexington Plain.

Although there are only two distinct physiographic units recognized in this report, this part of the basin may be divided into four physiographic types. The Kanawha Section, which includes the Eastern Coal Field region, has narrow ridges and crooked, steep-sided valleys. The relief increases from about 300 feet near the Ohio River to more than 2,000 feet in the south near Pine Mountain. The Knobs is an area of conical hills with rather broad valleys. The Outer Blue Grass is rather gently rolling except where the major streams have entrenched themselves into deep valleys. The Inner Blue Grass is a rather gently rolling upland, which is characterized by rather large sinkholes and springs. These physiographic changes reflect boundaries between the underlying rock units, from which changes in ground-water conditions may be interpreted. For example, in the area around Lexington, in the Inner Blue Grass region, which is underlain by soluble limestone, much of the drainage is underground.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

The most important source of ground water in the entire area covered by this report is the alluvial deposits along the Ohio River. The deposits range from about one-half mile wide near Covington to more than 2 miles wide near Lawrenceburg, Indiana, and in places are over 150 feet thick.

The Ohio River alluvial deposits from Maysville to Covington average about 1 mile in width, and are about 100 feet thick. The city of Maysville obtains its water directly from the Ohio River, but a local industry pumps as much as 800 gpm of water from a single well. At Augusta, west of Maysville, the city obtains its water from wells that reportedly yield as much as 500 gpm and average about 100 feet in depth. At Silver Grove, a local industry reportedly pumps as much as 1,000 gpm from a single well 100 feet deep. In the Newport-Covington area, local industry pumps as much as 400 gpm from individual wells in the same aquifer. The wells average about 100 feet in depth, although some are more than 150 feet deep.

The alluvium in the Licking River valley, which has a wider floodplain than the Kentucky River, is as much as 2 miles wide near Butler. However, there are no large withdrawals of ground water from the deposits and data are scarce. Wells are drilled more than 150 feet into the unconsolidated deposits. The largest reported withdrawals, 60 gpm, are obtained near Covington. This yield may reflect only the demand of the user at the point of need, and may not reflect the capacity of the aquifer to yield water to wells.

West of Covington, the Ohio River valley narrows to one-half mile or less, and wells reportedly yield 25 to 200 gpm. One of the deepest wells in the area between Maysville and Madison, 165 feet, is located about 5 miles west of Covington. At Lawrenceburg, the Ohio River valley widens to more than 2 miles and the glacial and alluvial deposits supply ground water to several industrial users.

From Lawrenceburg to Carrollton, the alluvium averages about 1½ miles in width, and is as much as 140 feet thick. The town of Warsaw obtains its water from the alluvial deposits and reportedly pumps more than 250 gpm from individual wells, and a nearby industry pumps more than 400 gpm from one well.

At Carrollton, the alluvial deposits exceed 2 miles in width and are about 100 feet thick. Carrollton obtains its water supply from wells drilled into the Ohio River alluvium. The wells reportedly yield more than 500 gpm each. The Carrollton Sand and Gravel Company pumps about 1,000 gpm from a well 130 feet deep.

Alluvium in the lower Kentucky River is as much as 2 miles wide and 135 feet thick. The most extensive deposits are located in the reach from Gratz, about 20 miles below Frankfort, to its confluence with the Ohio at Carrollton. There are no large withdrawals of ground water in the area, and hydrologic data are scarce. Sand and gravel operations in the valley, however, indicate the presence of permeable materials, and thus the potential for future ground-water development.

From Carrollton to Madison, the Ohio River alluvium averages about 1½ miles in width and about 130 feet in thickness. Only a few wells are drilled along this stretch of the river, and the maximum reported yield is about 250 gpm.

Water in the unconsolidated deposits along the Ohio River is very hard, varying from about 250 to 340 mg/l (table 9). Also, the water generally has objectionable concentrations of iron. No samples of ground water from the alluvium along the Kentucky and Licking Rivers are available, but because of the geologic setting of these basins, the water unquestionably will be hard and also contain objectionable amounts of iron.

TABLE 9.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE LICKING AND KENTUCKY RIVER BASINS.

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (^{o}F)
		Unconsolidated Sediments								
Glacial and alluvial sand and gravel in the Chio River valley, Maysville to Madison	10-80	100-1,000	80-160	---	250-350	20-70	5-20	0.01-0.2	300-450	53-58
Sand and gravel of alluvium in the Licking River valley	5-20	5-50	100-150	---	---	---	---	---	---	53-58
Sand and gravel of alluvium in the Kentucky River valley	10-30	100-300	60-130	---	---	---	---	---	---	53-58
		Bedrock Formations								
Limestones of the Middle Ordovician Series[a]	---	5-200 (springs 100-900)	50-200	---	150-800	10-400	5-500	0.01-10	200-800	53-58
Sandstones of the Pennsylvanian System	---	100-500	100-500	---	50-150	2-100	5-150	0.1-5	---	53-58
Limestones of the Upper Ordovician Series[a]	---	1-100	35-300	---	150-800	5-500	5-500	0.01-5	360-750	53-58

[a] Data do not include analyses of highly mineralized water from great depths, nor water contaminated by oil-field brine or man-made wastes.

Bedrock Formations

The area covered by this report is underlain by Paleozoic rocks that dip gently to the southeast and west from the Cincinnati Arch running through the center of the basins (pl. 19). Because of the gentle dip, the rocks crop out in wide bands across the area. Included in the bedrock systems are strata of limestone, sandstone, and shale.

The headwaters area of the Kentucky and Licking Rivers is in the Kanawha section, Eastern Coal Field region, where the major sources of ground water are the Breathitt and Lee Formations of Pennsylvanian age. The Pennsylvanian rocks in this area have a maximum thickness of more than 3,000 feet. The Breathitt and Lee Formations are similar in hydrologic character, but are dissimilar in lithologic character. The Lee Formation is a well sorted, fine- to medium-grained sandstone that is conglomeratic in places. The Breathitt Formation is a poorly sorted, fine- to very fine-grained sandstone that contains much shale. Because water in these formations is derived principally from the fractures and joints at shallow depths, the lithology is relatively important; however, the Lee Formation is generally more productive at depths where fractures and joints are fewer, because of its coarser texture. Both the Breathitt and Lee Formations are sources of municipal and industrial water supplies; wells drilled into the Breathitt Formation reportedly yield more than 500 gpm, and wells drilled into the Lee Formation reportedly yield as much as 900 gpm. More typical yields to wells in these formations, however, are about 25 to 50 gpm; the larger yields being found in stream valleys where rock fractures are likely to be larger and more numerous, and receive water from runoff from the hills as well as from the streams themselves.

Water samples from the Breathitt and Lee Formations ranged from soft to hard (10-175 mg/l), and the chloride content in all analyses from the shallower wells was below the suggested maximum for drinking water. In general, the chloride content of the water increases with the depth of the well below drainage. Salty water generally is encountered at depths greater than 300 feet, and may occur at depths below 100 feet. The iron content of most of the analyses is high enough to require treatment for public supply purposes.

The next bedrock system crossed by the Kentucky and Licking Rivers as they flow northward are strata of Mississippian age. The first rocks crossed by the rivers are fairly thick-bedded limestones with numerous shaly partings. These rocks form steep-sided slopes and the tops of some

ridges. Many of the thicker limestones project out as ledges and small cliffs along hillsides. Continuing northward, the Mississippian rocks are predominantly shale and siltstone. These siltstones and shales form the main part of the Knobs area of Kentucky. The Mississippian rock strata, which are 600 to 700 feet thick, are generally poor sources of water and yield only small amounts for domestic use. The quality of the water from these rocks, particularly the shales, is very poor, generally being saline.

Upon leaving the Mississippian rocks in Madison County, the Kentucky River crosses a belt of Devonian and Silurian rocks, and the Licking River crosses this belt of rocks in Bath County. The Devonian rocks are predominantly shales that are about 170 feet thick, and are underlain in places by as much as 25 feet of limestone. The Silurian rocks are also predominantly shales, which are about 100 feet thick and are underlain by limestone as much as 20 feet thick. The shales of both the Devonian and Silurian Systems are inadequate sources of water supply for other than domestic needs, and the limestones yield almost no water to wells. The water from the shale is generally highly mineralized.

The rock system next crossed by the Kentucky and Licking Rivers is divided, for the purpose of this report, into the Upper Ordovician and Middle Ordovician Series. Both of these divisions lie within the Blue Grass region of Kentucky. The Upper Ordovician Series consists of the Richmond, Maysville, and Eden Groups, which form the bedrock surface of the Outer Blue Grass region, and have a combined thickness of more than 500 feet. These rocks are predominantly limestone with numerous shale partings. Wells drilled into the limestones generally yield adequate supplies of water for domestic use, and in a few areas, yields of as much as 100 gpm are obtained from thick limestones of the Maysville Group. Water from the limestones is very hard, and in some areas may contain salt or hydrogen sulfide. Near Blue Lick Springs, the Licking River crosses the Maysville Fault, but the effect of this fault zone on the quantity and quality of water in the areas cannot be determined on the basis of available data.

At the Clark-Madison County line, the Kentucky River swings southwestward as it encounters the Kentucky River fault zone (pl. 19). The river follows this fault zone for about 15 miles and then again swings northward across Middle Ordovician limestones that underlie Lexington within the Inner Blue Grass region. These limestones are as much as 700 feet thick and contain numerous solution openings, but in places they contain shaly zones. The shaly zones are important hydrologically because they limit the circulation of water. In some places clay lenses reduce the permeability of the limestones. Wells drilled into the limestones generally yield adequate

quantities of water for domestic use and a few wells reportedly yield as much as 400 gpm. Because of the soluble nature of limestone, springs are numerous. Many of the springs have relatively high flows, more than 500 gpm. The water in the limestones is generally very hard, and many wells report excessive amounts of chloride and hydrogen sulfide. Because of the direct connection between the surface and the openings in the limestone, aquifer contamination has been a serious problem in the Lexington area. Lexington obtains its water supply via a pipeline to the Kentucky River.

CURRENT STATUS OF GROUND-WATER INFORMATION

Reconnaissance-type reports that describe in rather broad terms the ground-water resources have been published for the entire state of Kentucky. These reports, prepared by the U.S. Geological Survey in cooperation with the state of Kentucky, divide the state into physiographic units and discuss in general terms the ground-water resources within each unit. In addition, detailed reports on ground water in specific areas, including the entire reach of the Ohio River along Kentucky's border, have been published by the U.S. Geological Survey in cooperation with the state of Kentucky. Information on geology and ground-water yields for the Ohio River alluvium on the north side of the river is given on a series of underground water-resources maps published by the Ohio Division of Water.

Bibliographic citations for the more significant ground-water reports covering areas of county-size or larger are as follows:

Hamilton, D.K., 1950, Areas and principles of ground-water occurrence in the Inner Bluegrass region, Kentucky: Kentucky Geol. Survey, Ser. 9, Bull. 5, 68 p.

Hendrickson, G.E., and Krieger, R.A., 1964, Geochemistry of natural waters of the Blue Grass region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1700, 135 p.

Kirkpatrick, G.A., Price, W.E., Jr., and Madison, R.A., 1963, Water resources of eastern Kentucky - Progress report: Kentucky Geol. Survey, ser. 10, Rept. Inv. 5, 67 p.

Kulp, W.K., and Hopkins, H.T., 1960, Public and industrial water supplies of Kentucky: Kentucky Geol. Survey, Inf. Ser. 10, Circ. 4, 102 p.

Ohio Division of Water, 1958, Ohio water plan inventory project: Ohio Dept. Natural Resources, underground water-resources maps J, K-6, and L-3.

Palmquist, W.N., and Hall, F.R., 1961, Reconnaissance of ground-water resources in the Blue Grass region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1533, 39 p.

Price, W.E., Jr., 1964a, Geology and hydrology of alluvial deposits along the Ohio River between the Manchester Islands and Silver Grove, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-94.

______ 1964b, Geology and hydrology of alluvial deposits along the Ohio River between Ethridge and the Twelvemile Island, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-97.

______ 1964c, Geology and hydrology of alluvial deposits along the Ohio River between Newport and Warsaw, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-98.

Price, W.E., Jr., Mull, D.S., and Kilburn, Chabot, 1962, Reconnaissance of ground-water resources in the Eastern Coal Field region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1607, 56 p.

Walker, E.H., 1953, Geology and ground-water resources of the Covington-Newport alluvial area, Kentucky: Kentucky Geol. Survey Circ. 240, 26 p.

______ 1957, The deep channel and alluvial deposits of the Ohio Valley in Kentucky: U.S. Geol. Survey Water-Supply Paper 1411, 25 p.

More data are needed to determine the depths and yields of fresh-water aquifers within the consolidated deposits, and from the unconsolidated alluvial deposits along the Kentucky and Licking Rivers. Also, more detailed investigations are needed along the Ohio River where ground-water resources undoubtedly will be extensively used in future development.

MANAGEMENT CONSIDERATIONS

Large supplies of ground water for municipal and industrial uses are available from the alluvium along both sides of the Ohio River between Maysville, Ky., and Madison, Ind. The amount of ground water that can be developed from these deposits, however, is limited by the rate at which water can move from the river. For this reason, the hydrologic effects on the unconsolidated valley-fill deposits created by new navigation facilities on the Ohio River should be studied in detail for a planning guide to future development. Such studies should consider the effects of sediment transport and deposition on recharge rates, and also changes in quality of the recharge water. Also, the increased heads in the river created by the new dams and locks will undoubtedly stimulate crop irrigation, but also may have detrimental effects, such as water logging of the soil.

Much additional testing should be done in the alluvium along the Kentucky and Licking Rivers to determine their adequacy and suitability for future needs. Industrial expansion and development will generally be established in areas where an adequate supply of water is known to be available.

In addition to the large quantities of ground water available from the alluvium in the major stream valleys, there is some potential for development from the Pennsylvanian sandstones and Ordovician limestones. These consolidated bedrock aquifers locally have provided fairly large supplies of water at a number of places within the drainage basins. At several locations, the quality of water should be more thoroughly investigated, particularly to learn more about the occurrence of saline water in the Eastern Coal Field region, and to delineate more accurately the horizon or horizons at which it occurs. Studies need to be made of the surface water-ground water relationship in the limestone areas to learn more about the quality characteristics of the water, and man's influence on this quality. This is particularly true in the Lexington area where the large cavernous limestones are sometimes used, either inadvertently or directly for the disposal of wastes. The water-quality problems in the area covered by this report have been recognized by the U.S. Public Health Service, which has accordingly provided for the further study of ground-water quality conditions in the area.

Insofar as potential development and management techniques are concerned, special consideration should be given to the Lexington area, the region's most important and rapidly growing industrial complex. The city is located on a structural dome, and in the divide area between several streams draining the area. It has very little upbasin or watershed area to

naturally collect and deliver water. The limestone aquifer underlying Lexington and vicinity is highly susceptible to contamination, and according to local health officials, 90 percent of the wells are contaminated. The general movement of underflow appears to be radial away from the dome and the city, but the actual flow is in solution openings in the limestone. An important management decision to be made is whether or not to consider all or part of the local water resource as contaminated and, if so, whether it is feasible to abate the pollution and reclaim the aquifer, which must be done if maximum beneficial use is to be made of the ground-water resources of the Lexington area.

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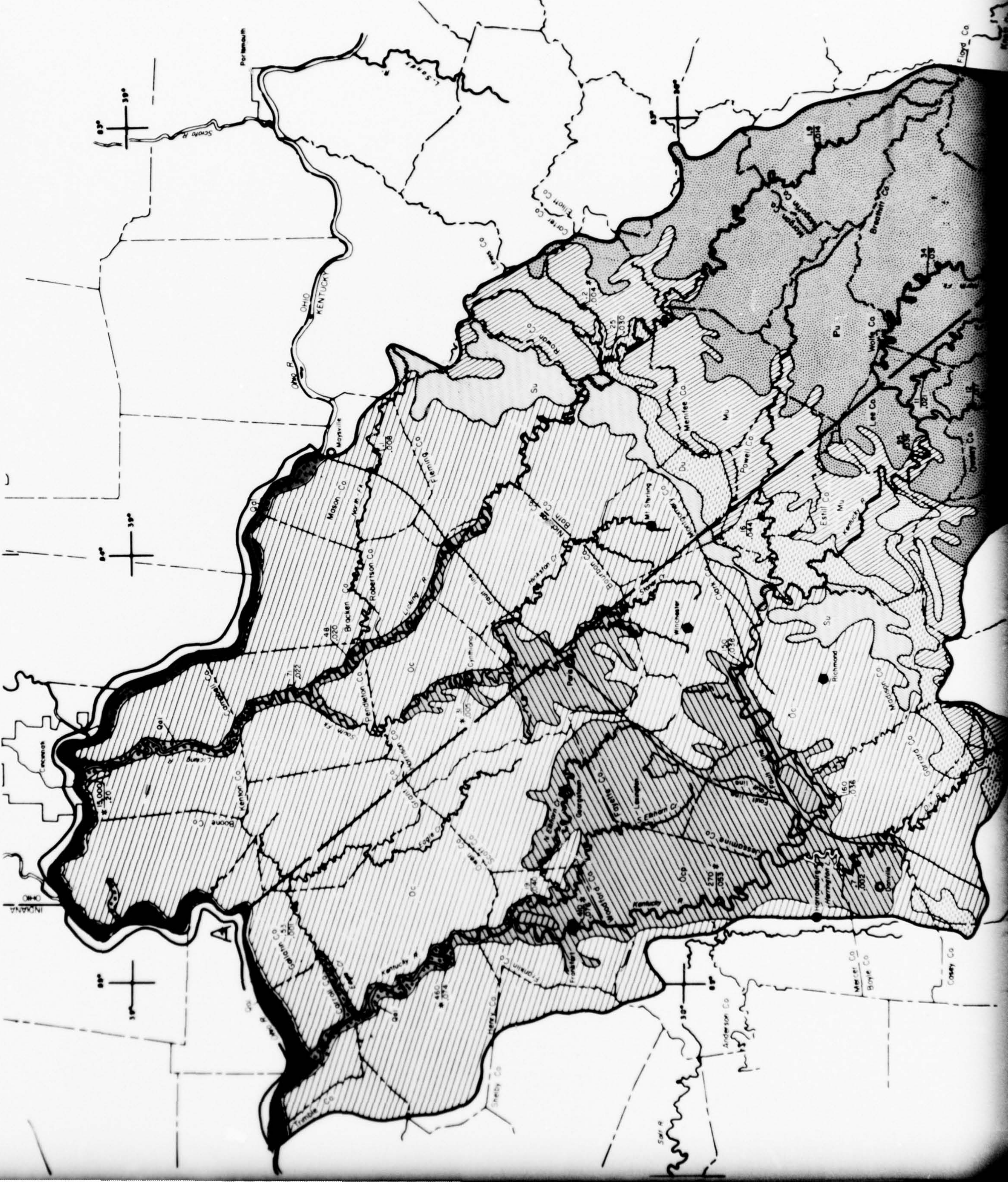

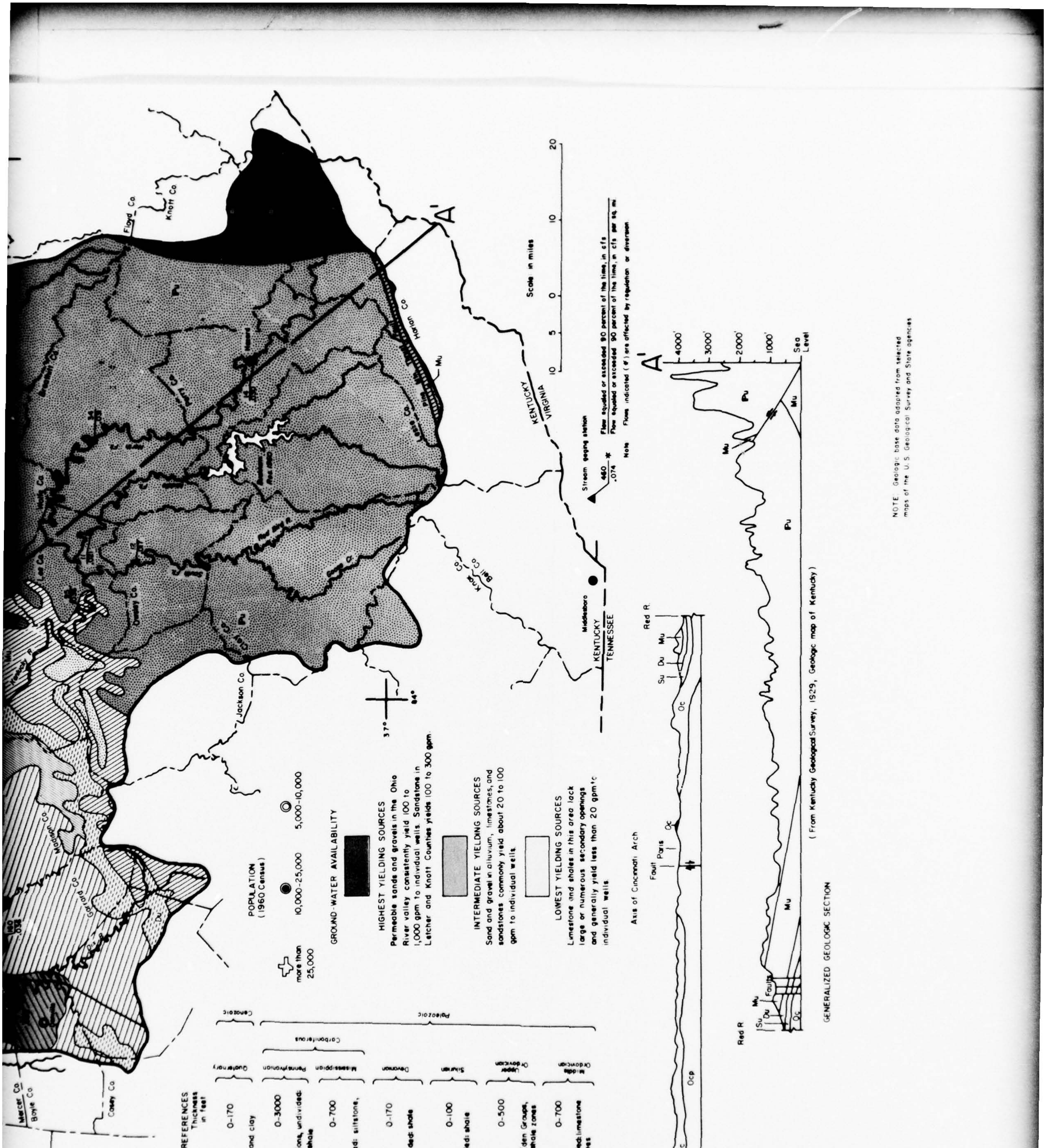

LICKING AND KENTUCKY RIVER BASINS
SOURCES OF GROUND WATER

PLATE 19

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 10

WABASH RIVER BASIN

By

Frank A. Watkins, Jr., and Paul R. Jordan

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

WABASH RIVER BASIN

CONCLUSIONS

Large supplies of ground water are available for further development in the Wabash River basin. Excellent ground-water sources are widely distributed in most parts of the basin, except for about 13,000 square miles south of the limit of Wisconsin Glaciation. The magnitude of the supply is indicated by the overflow of ground water into the rivers; based on the dry-weather flow of the Wabash River near its mouth, the net aggregate ground-water discharge to the streams is at least 3,400 cfs, the 90 percent-duration flow, and probably exceeds 5,600 cfs, the 75 percent-duration flow.

Much of this flow is from the shallowest of the three principal sources, the glacial outwash, which near the major streams yields more than 500 gpm to wells less than 200 feet deep. The other principal sources of ground water, in order of estimated potential, are extensive limestone formations in the northeastern part of the basin, and filled pre-glacial river valleys. The limestones yield 150 to 500 gpm to many wells that penetrate about 300 feet of the rock, but deeper wells in the limestone commonly produce salty water. A filled river valley extending west from Tippecanoe County, Indiana, yields 100 to 500 gpm to wells 100 to 400 feet deep.

Nearly all the water from the three major sources has hardness in excess of 250 mg/l, and contains iron in excess of 1 mg/l, but is suitable for most uses after moderate treatment.

SOURCES AND DISTRIBUTION OF GROUND WATER

The bedrock of the basin consists of sedimentary rock strata varying in hydrologic properties from shale yielding little or no water to limestone yielding large quantities of water. The bedrock is overlain by glacial drift in nearly all of the basin; only a relatively small area in the southern part of the basin is devoid of drift. Both the bedrock and the unconsolidated materials overlying it include major aquifers. The bedrock aquifers characteristically underlie broad areas, while the unconsolidated aquifers characteristically are long and very narrow. The distribution of ground water particularly favors the northeastern section of the basin, which has good aquifers in both unconsolidated sediments and bedrock formations.

Unconsolidated Sediments

The best unconsolidated aquifers consist of sand and gravel outwash deposited in the major river valleys. Most of these deposits are exposed at the surface in the valleys, but some are covered by post-glacial river alluvium, by glacial till, or by wind-blown sand, and hence are not always shown on surface geology maps. In the extreme northern part of the basin, water from outwash deposits in the Tippecanoe valley and on the adjoining plain discharge to the Tippecanoe River. At Ora, the river has the highest dry-weather flow in the basin, 0.23 cfs per square mile (pl. 20), indicating that these sediments have excellent potential for future development. The valley of the Wabash River holds large concentrations of permeable sand and gravel along almost its entire reach of more than 300 miles, from near Ft. Wayne to the Ohio River. The Wabash River valley holds great potential for future water development. Important supplies of ground water are also available for development in glacial deposits in the drainage areas of the upper White and East Fork of the White, and in the valley of the lower White River.

In Tippecanoe County, Indiana, and westward, the filled valley of the ancient Teays River (called the Mahomet in Illinois) contains thick deposits of sand and gravel and supplies good quantities of water to wells. The other major valleys and the eastern reach of the Teays in the Wabash basin have been largely filled with silt and clay of low permeability and contain only moderate thicknesses of sand and gravel, or none at all. The permeable sediment contained in the Teays Valley in eastern Illinois and western Indiana is generally more than 100 feet below the land surface except near a few streams, and it therefore has no pronounced effect on the dry-weather flow of the overlying streams. The only such contributions indicated by plate 20 are to Salt Fork of the Vermilion River near Homer (0.042 cfs per square mile), and West Branch of the Salt Fork at Urbana (0.050 cfs per square mile). These streams, together with the part of the Vermilion River overlying the filled valley, may be sources of recharge during times of high streamflow.

The most significant hydrologic and chemical characteristics of the major unconsolidated aquifers are summarized in table 10. For this summary, the aquifers are grouped by areas in which the characteristics are fairly similar. Minimum ground-water discharges to the streams (based on the flows exceeded 90 percent of the time) from various areas in the basin are as follows: Tippecanoe and upper Wabash, 750 cfs; middle Wabash, 700 cfs; lower Wabash, 750 cfs; upper White and East Fork White, 650 cfs; lower White, 650 cfs.

TABLE 10.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE WABASH RIVER BASIN.

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Total dissolved solids (mg/l)
		Unconsolidated Sediments*						
Outwash and valley train deposits in drainage of Tippecanoe and upper Wabash (to Delphi)	12-50	400-1,000	30-130	0-30	300-450	40-380	6-30	350-450
Outwash and valley train deposits along middle Wabash (Delphi to Terre Haute)	20-50	600-1,000	100-200	50-120	250-400	45-110	2-25	300-400
Outwash and valley train deposits along lower Wabash (Terre Haute to mouth)	20-50	500-1,500	30-120	5-30	250-400	25-75	1-17	220-450
Outwash and valley train deposits in drainage of upper White (to Martinsville) and upper East Fork White	15-80	400-1,000	30-120	1-50	300-400	40-90	4-55	400-600
Outwash and valley train deposits in drainage of lower White (Martinsville to mouth)	15-65	200-600	45-120	10-30	250-400	25-90	1-35	350-370
Filled Teays (Mahomet) Valley from Tippecanoe County west	15-100	100-500	110-340	20-100	250-400	2-100	0-20	320-420
		Bedrock Formations**						
Silurian limestone and dolomite in northeast part of basin (low-sulfate area)	---	150-400	145-330	10-50	330-500	50-100	3-80	350-650
Devonian limestone and dolomite in high-yield area of Indiana	---	150-500	250-450	10-30	320-360	0-130	2-40	350-400
Silurian limestone and dolomite in far northeast part of basin (high-sulfate area)	---	150-500	200-300	20-30	400-860	250-650	5-15	450-1450
Mississippian sandstone in Montgomery, Fountain, and Putnam Counties, Indiana	---	100-300	50-200	20	290-420	10-100	4-35	330-470
Devonian limestone and dolomite in Douglas and Champaign Counties, Illinois	---	150-400	600-700	90-130	230-250	10	20-80	410-510

* Areas delineated on plate 20 as "higher-yielding sources".
** Areas delineated on plate 21 as "higher-yielding sources".

As table 10 shows, the chemical characteristics are not distinctively different between the various areas. In addition to the characteristics shown in the table, the waters in all the aquifers described have pH values between 7 and 8, temperatures of 52 to 57°F, and iron content typically between 1 and 3 mg/l. Because of its hardness and high iron content, the water generally is treated before use in municipal supplies and industrial applications. Concentrations of sulfate and chloride, with few exceptions, are well below the limits suggested by the U.S. Public Health Service for drinking water. In the extreme northeastern part of the basin, however, unconsolidated aquifers are in contact with bedrock containing water of high sulfate content. Under certain conditions, pumping of a well in the unconsolidated material can induce movement of water from the bedrock into the well. This has been observed in two wells in Adams and Grant Counties, Indiana.

Over much of the northern half of the basin, lenses of saturated sand and gravel interbedded with the much less permeable till were deposited during several intervals of glaciation. These lenses are not as thick as the major aquifers previously discussed and are not as readily recharged, but they can supply sufficient water for small municipal or industrial supplies. The distribution of permeable sediments within the till is highly irregular, but they are more likely to be found where the glacial drift is thick than where it is thin. The broad areas shown as "intermediate yielding sources" on plate 20 are based mainly on the thickness of the drift and well data, which shows that many wells tapping these deposits yield 20 to 100 gpm.

The valleys of the Embarrass, Little Wabash, and lower East Fork of the White contain sediments that are generally thinner and less permeable than those in the other major valleys. The saturated portions of these sediments can support moderate pumpage rates and have the advantage, not shared by the sand and gravel lenses in the till, of being adjacent to good sources of recharge.

Bedrock Formations

Some of the bedrock strata underlying the Wabash River basin are also important sources of ground water. Except for a small area in southern Indiana, the bedrock is covered by unconsolidated sediments that range in thickness from a few feet in southern areas to as much as 400 feet in the filled valleys in northern areas. The bedrock is composed of strata from rock systems ranging in age from Ordovician to Pennsylvanian. The various formations or groups of formations that comprise these rock systems are not differentiated herein. The most significant hydrologic and chemical characteristics of the high-yielding sources of ground water in the bedrock are summarized in table 10.

The principal sources of water in the bedrock are the limestones and dolomites of the Silurian and Devonian Systems (pl. 21). These rocks underlie the northeastern part of the basin except in small areas where pre-glacial streams have cut valleys into the underlying Ordovician shales. The limestones and dolomites yield more than 100 gpm to wells in an area of about 8,000 square miles. Most of the wells tapping these rocks yield from 150 to 500 gpm, although higher and lower yields have been reported. Fracture zones and solution channels containing water are common in the shallow strata, but are smaller and less abundant at greater depths. Highest yields normally are obtained at high parts of the local bedrock topography, where the largest and most numerous openings are present. Wells drilled more than 300 feet into the limestone and dolomite gain very little yield, and the water from these depths generally is excessively mineralized.

In Illinois, good yields of ground water can be obtained from a small area in which Devonian rocks are at or near the top of the LaSalle Anticline. Existing high-yield wells in the area are more than 600 feet deep, but good yields probably could be obtained at lesser depths in part of the area. Toward the south, these rocks are too deep for serious consideration as a source of fresh water.

Waters from the sources shown on table 10 most commonly have pH values ranging from 7.2 to 7.8, and iron from 1 to 3 mg/l. The temperatures of water from all the high-yield sources in Indiana and Ohio range from 52 to 58^{o}F, but water from the 600 to 700-foot wells in the Devonian rocks in Illinois ranges from about 59 to 66^{o}F. The high iron content and hardness throughout the high-yield area make treatment of the water desirable if used for municipal supply and necessary for most industrial uses. Concentrations

of chloride are desirably low, and concentrations of sulfate, except in one area, are lower than the limit suggested by the U.S. Public Health Service for drinking water. In the area of Ohio and northeastern Indiana shown on plate 21, sulfate content is generally more than 250 mg/l, and hardness and total dissolved solids are considerably higher than in the other areas.

Strata of the Mississippian and Pennsylvanian Systems underlie very large areas of the western and southern parts of the basin, and consist of a wide variety of rock types (pl. 21). The shale, clay, coal, and siltstone formations yield little, if any, water, and yields from the sandstones and limestones are moderate. In most of the area underlain by these rocks, users of large supplies of ground water rely on the unconsolidated aquifers rather than on the bedrock aquifers. In some very small areas near the center of the basin, wells produce more than 150 gpm from sandstone aquifers.

CURRENT STATUS OF GROUND-WATER INFORMATION

Detailed reports on ground-water conditions have been published for areas totaling about one-fifth of the basin. Reconnaissance-type reports have been published for about one-fourth of the basin. The following reports are the principal sources of information for areas of county size or larger:

Brown, E.A., 1949, Ground-water resources of Boone County, Indiana: Indiana Div. Water Resources Bull. 4, 152 p.

Illinois State Water Survey, 1962, Potential water resources of southern Illinois: Rept. Inv. 31, 97 p.

Indiana Water Resources Study Committee, 1956, Indiana water resources, technical appendix: 127 p.

Klaer, F.H., Jr., Davis, G.E., and Kingsbury, T.M., 1951, Ground-water resources of the Columbus area, Bartholomew County, Indiana: Indiana Div. Water Resources, 37 p.

Pryor, W.A., 1956a, Ground-water geology in southern Illinois--A preliminary geologic report: Illinois State Geol. Survey Div. Circ. 212, 25 p.

______ 1956b, Ground-water geology of White County, Illinois: Illinois State Geol. Survey Div. Rept. Inv. 196, 50 p.

Roberts, C.M., Widman, L.E., and Brown, P.N., 1955, Water resources of the Indianapolis area, Indiana: U.S. Geol. Survey Circ. 366, 45 p.

Rosenshein, J.S., 1958, Ground-water resources of Tippecanoe County, Indiana: Indiana Div. Water Resources Bull. 8, 38 p.

Rosenshein, J.S., and Hunn, J.D., 1964a, Ground-water resources of northwestern Indiana--Preliminary report, Fulton County: Indiana Div. Water Resources Bull. 21, 83 p.

______ 1964b, Ground-water resources of northwestern Indiana--Preliminary report, Pulaski County: Indiana Div. Water Resources Bull. 24, 71 p.

Selkregg, L.F., and Kempton, J.P., 1958, Groundwater geology in east-central Illinois--A preliminary geologic report: Illinois State Geol. Survey Div. Circ. 248, 36 p.

Selkregg, L.F., Pryor, W.A., and Kempton, J.P., 1957, Ground-water geology in south-central Illinois--A preliminary geologic report: Illinois State Geol. Survey Div. Circ. 225, 30 p.

Watkins, F.A., Jr., and Jordan, D.G., 1961, Ground-water resources of west-central Indiana--Preliminary report, Greene County: Indiana Div. Water Resources Bull. 11, 255 p.

_____ 1962a, Ground-water resources of west-central Indiana--Preliminary report, Sullivan County: Indiana Div. Water Resources Bull. 14, 345 p.

_____ 1962b, Ground-water resources of west-central Indiana--Preliminary report, Clay County: Indiana Div. Water Resources Bull. 16, 309 p.

_____ 1963a, Ground-water resources of west-central Indiana--Preliminary report, Owen County: Indiana Div. Water Resources Bull. 18, 99 p.

_____ 1963b, Ground-water resources of west-central Indiana--Preliminary report, Vigo County: Indiana Div. Water Resources Bull. 17, 358 p.

_____ 1964a, Ground-water resources of west-central Indiana--Preliminary report, Putnam County: Indiana Div. Water Resources Bull. 21, 83 p.

_____ 1964b, Ground-water resources of west-central Indiana--Preliminary report, Parke County: Indiana Div. Water Resources Bull. 23, 125 p.

_____ 1965a, Ground-water resources of west-central Indiana--Preliminary report, Montgomery County: Indiana Div. Water Resources Bull. 27. (In press)

_____ 1965b, Ground-water resources of west-central Indiana--Preliminary report, Fountain County: Indiana Div. Water Resources Bull. 28. (In press)

_____ 1965c, Ground-water resources of west-central Indiana--Preliminary report, Vermillion County: Indiana Div. Water Resources Bull. 29. (In press)

Watkins, F.A., Jr., and Ward, P.E., 1962, Ground-water resources of Adams County, Indiana: Indiana Div. Water Resources Bull. 9, 67 p.

The information currently available, as given in this report and the other reports listed, is nearly adequate for general planning purposes. More information would be desirable concerning the recharge-discharge relationships of surface water and ground water in areas of large present or projected withdrawal, such as near Kokomo, Lafayette, Terre Haute, Indianapolis, and Muncie. Also desirable would be some information on high-yielding aquifers that have not yet been identified within the areas now classified as having "fair" ground-water potential. Such aquifers of unconsolidated sediments probably could be found covered with till in Kosciusko and Fulton Counties, Indiana, and as extensions of the presently-known aquifers along and near the Wabash River upstream from Delphi and downstream from Riverton, and along and near the White and East Fork White Rivers. A third type of desirable information would be on the areas and rates of recharge and discharge of the high-yielding part of the Teays Valley.

Design of specific projects for further development of ground-water resources in almost all areas of the basin would require special studies to determine the hydraulic and chemical characteristics of the aquifers in the areas of development and to predict the effects of the developments. The need for such knowledge has been recognized by water-development agencies. Studies are being sponsored by the Corps of Engineers to determine the feasibility of developing ground-water supplies rather than surface-water supplies in areas of proposed multiple-purpose reservoirs, and to determine the effects of the reservoirs on the ground-water regimen. Such studies are in progress for the Patoka River, Clifty Creek, Embarrass River, Richland Creek, and Big Walnut Creek; studies of more than 20 other areas are planned.

MANAGEMENT CONSIDERATIONS

The Wabash River basin possesses one of the best aquifer systems in the Midwest, the sand and gravel outwash along the major river valleys. The outwash aquifers have great potential for future development. Significant ground-water developments have largely been limited to such cities as Lafayette and Indianapolis, where much ground water is used by industries, although even in those cities it is probable that further developments could be made without detrimental effects. These aquifers extend for more than 300 miles along the Wabash River and an even longer aggregate distance along the Tippecanoe, Eel, Embarrass, White, and several other tributaries. The potential for development stems from their high degree of permeability and their proximity to the rivers, which provide perennial sources of water for recharge. Because of the hydraulic connection between the rivers and the permeable sediments, the large natural potential could be further increased by use of various techniques of artificial recharge.

Considerable potential for additional development also exists in the northeastern part of the basin underlain by high-yielding limestone and dolomite aquifers. These aquifers have been tapped for large supplies in only a few places, and although they are not as permeable nor as readily recharged as the sand and gravel along the rivers, they provide opportunities for large-scale water development in areas that are not adjacent to the rivers.

A few areas in the basin lack the development potential for even moderate ground-water supplies. The largest of these areas are in the southern part of the basin, south of the limit of Wisconsin Glaciation, and away from the major stream valleys. Large-scale water development in these areas would necessitate surface storage of runoff, and conditions are favorable for this kind of storage. Precipitation and runoff in the southern area are higher than in the remainder of the basin, and the hilly terrain provides many favorable sites for reservoirs. Scenic country side and sparsely populated areas combine to make the development of extensive recreational sites centered on surface impoundments distinctly possible.

In many places in the basin, the streamflow during dry weather is inadequate for assimilation of treated municipal and industrial wastes that are discharged into the streams. Although much of the waste is now treated and the degree of treatment is increasing, additional dilution water will be needed in the future to avoid inflicting hardships on downstream water users

and to maintain the recreational and esthetic values of the streams. There are several places where underground sources might be tapped to provide for needed low-flow augmentation or for transmission to points of need elsewhere in the basin. These include the bedrock above Kokomo, Indiana, which could be used to augment the dry-weather flow of Wildcat Creek, and both the bedrock and unconsolidated sediments above Muncie and Indianapolis, which could be tapped to augment the flow of the White River. Of course, the cost of using ground water for dilution would have to be considered versus the cost of surface water storage and the cost of an unusually high degree of treatment of the wastes. Use of ground water might prove to be most advantageous in some cases where good surface reservoir sites are not available or where surface storage solely for waste-dilution purposes would not be economically feasible.

About 24,000 acres of high-value crops in the basin received supplemental irrigation in 1955, and the irrigated area is expected, by the Indiana Water Resources Study Committee, to increase to about 45,000 acres by 1975. Ground water can have some important advantages over surface water for supplemental irrigation, in which the water is needed for only a short time during the year and may not be needed at all during some years. Where the ground water is available over a wide area, the supply can be developed within the tract to be irrigated, even on upland areas removed from the streams, thus eliminating costly pipelines or other means of delivering the water to the fields. Use of ground water for irrigation would also tend to minimize conflict with holders of riparian water rights. The quality of the ground water, although it generally has a higher mineral content than water in the streams, is suitable for the irrigation of most crops.

Increased irrigation outside the river valleys could be effectively supplied by ground water from the extensive limestone and dolomite aquifers in large parts of the upper Wabash, upper White, and upper East Fork of the White River drainage areas, and from the outwash-plain aquifer in the Tippecanoe River drainage area. Use of ground water for new irrigation supplies is particularly desirable in the upper East Fork of the White River drainage, in order to avoid conflict with uses of surface water for municipal and industrial supplies and waste assimilation (see Indiana Water Resources Study Committee technical appendix, p. 105).

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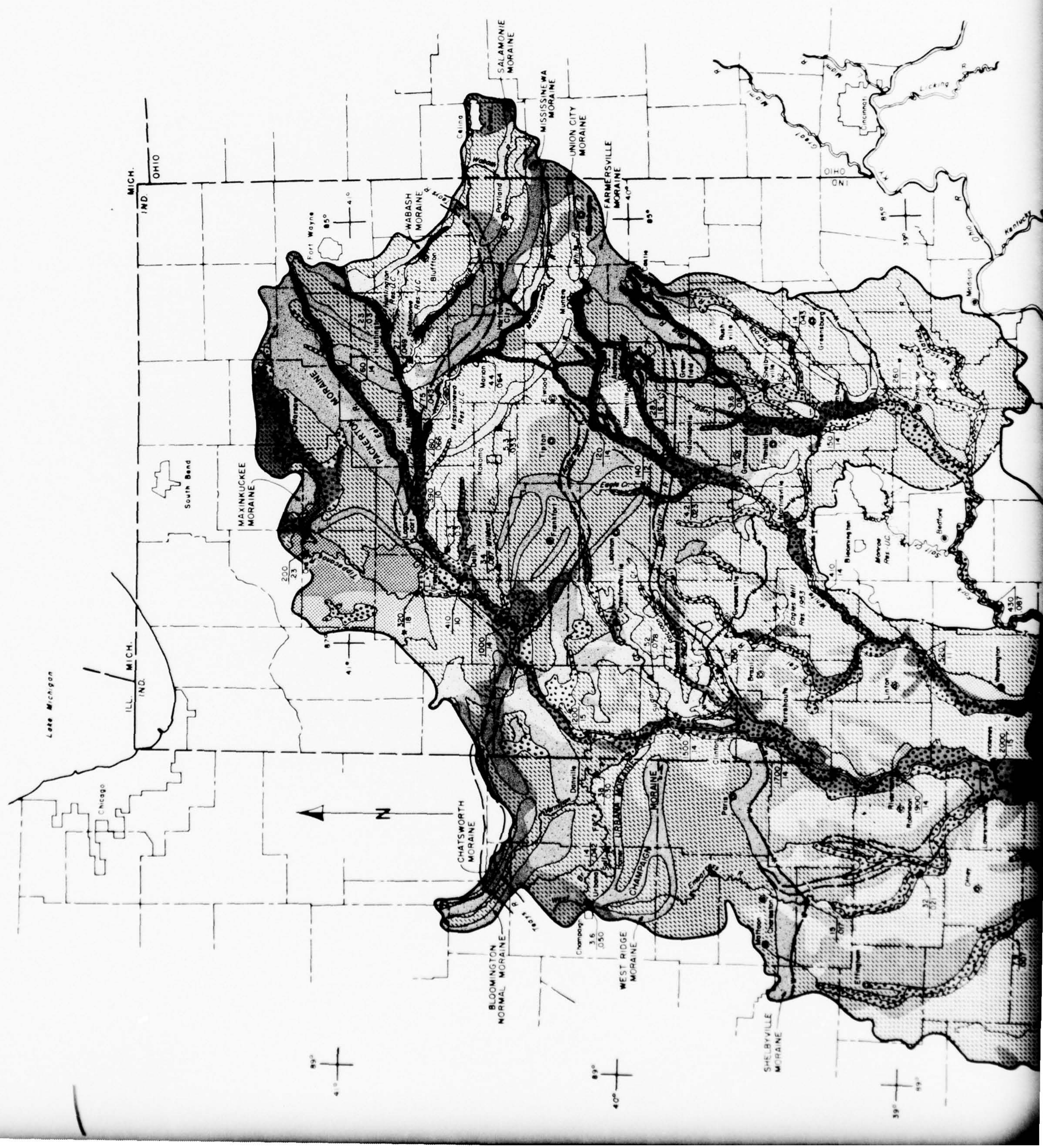
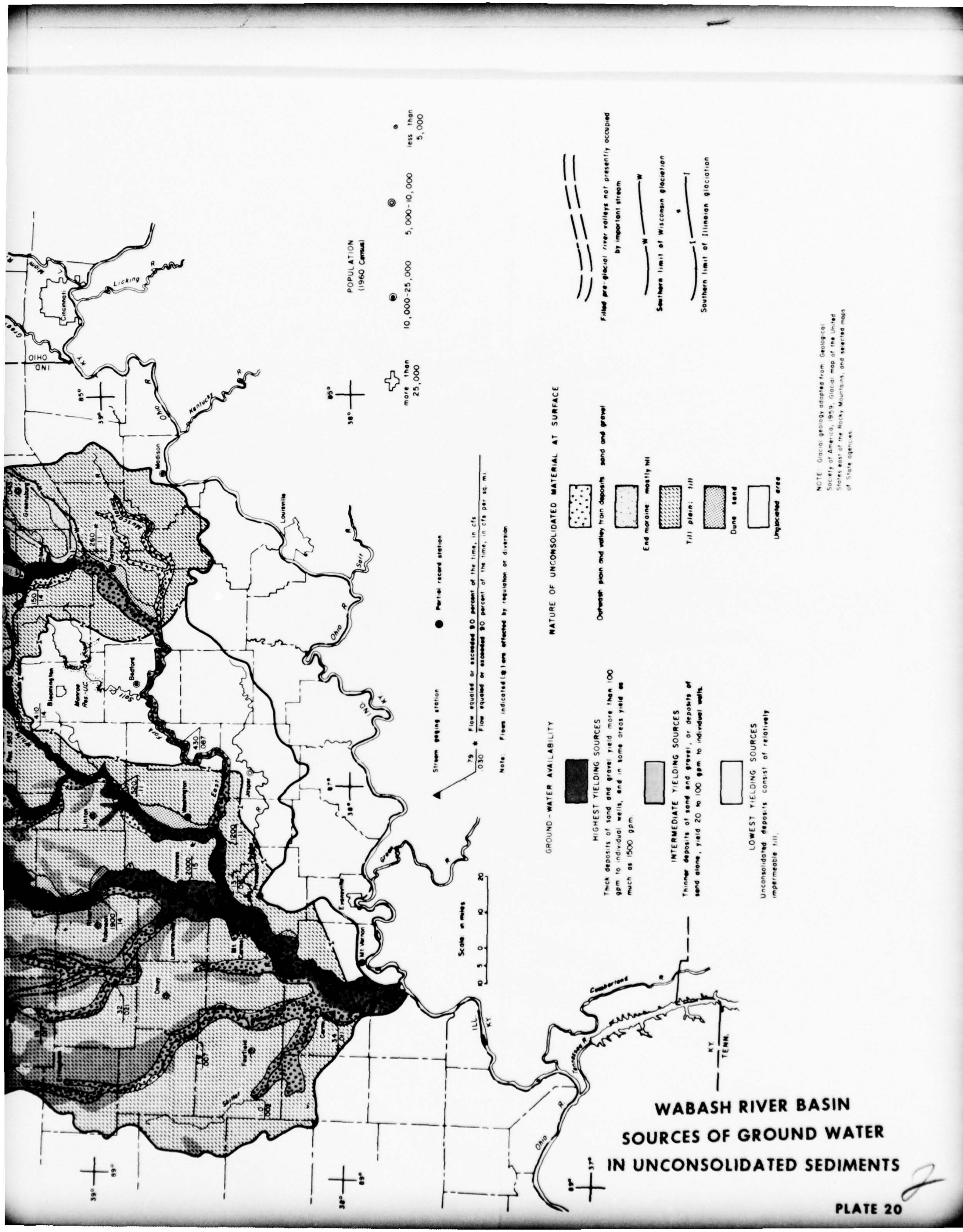
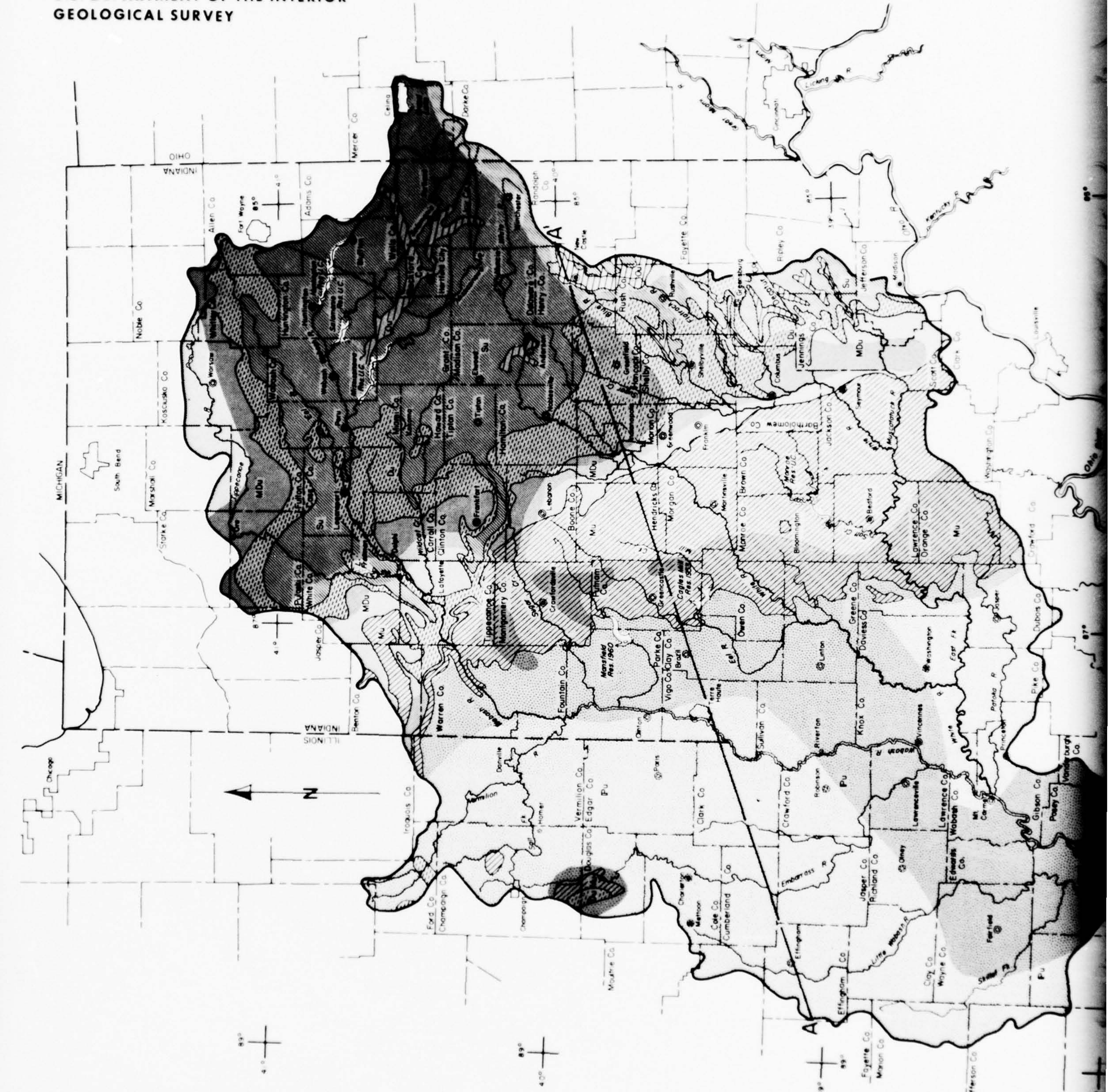


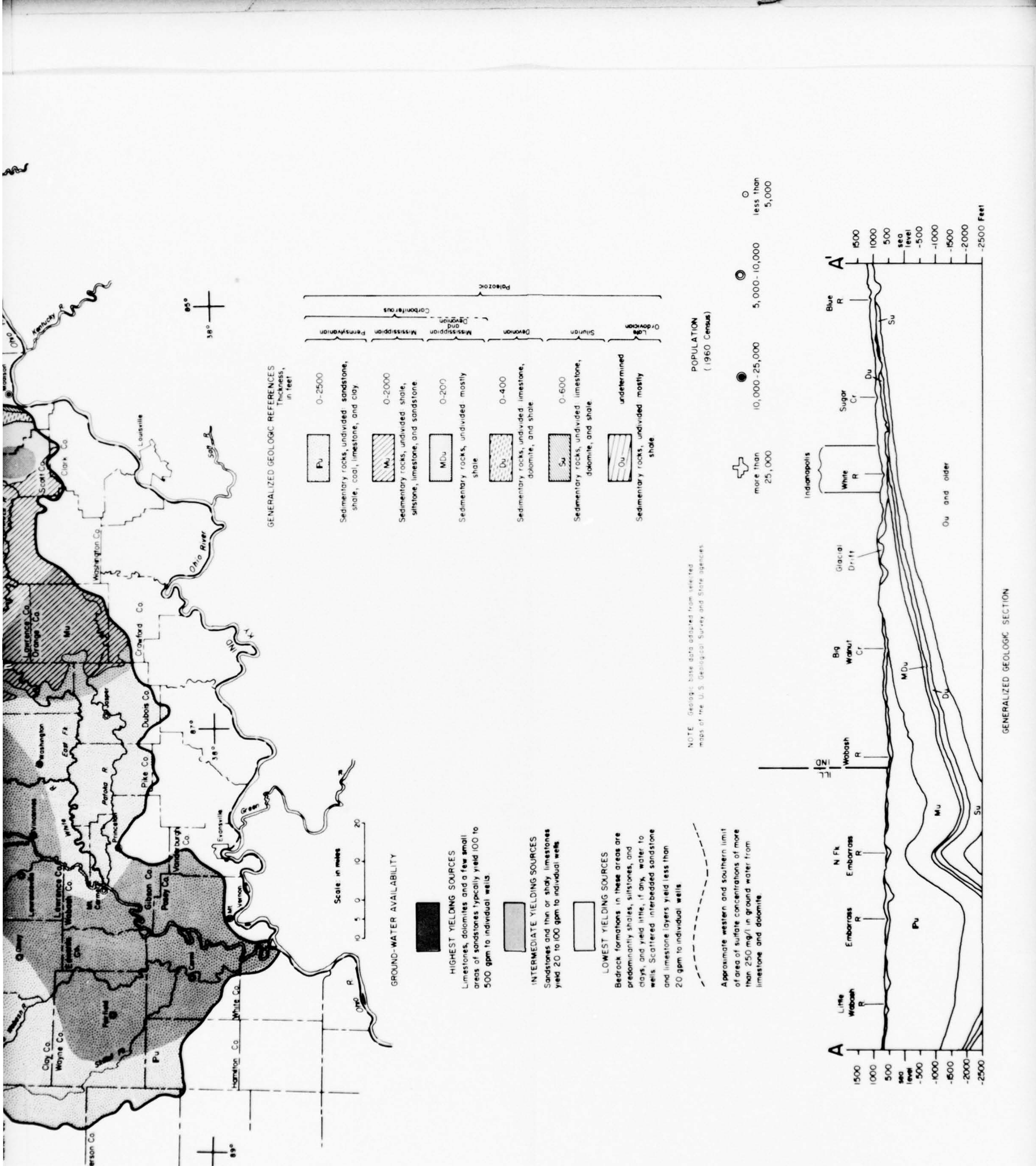


WABASH RIVER BASIN
SOURCES OF GROUND WATER IN UNCONSOLIDATED SEDIMENTS

PLATE 20

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY





WABASH RIVER BASIN
SOURCES OF GROUND WATER
IN BEDROCK FORMATIONS

PLATE 21

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 11

LOWER OHIO RIVER DRAINAGE AREA
(Area draining to the Ohio River between Madison and Cairo,
excluding the Wabash and Cumberland River Basins)

By

G.D. Dove, P.R. Jordan, and J.C. Wallace

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

LOWER OHIO RIVER DRAINAGE AREA
(Excluding the Wabash and Cumberland Basins)

CONCLUSIONS

Large supplies of ground water are available for present and future development from the glacial and alluvial valley-fill sediments along the Ohio River between Madison, Ind., and Cairo, Ill. The sediments are finer-grained and consequently less productive than those farther upstream in the Ohio Valley, but are capable of yielding many times the present ground water demands. Individual wells drilled into the valley fill range from about 50 to 110 feet in depth and reportedly yield as much as 1,500 gpm. The water is generally hard and has an excessive iron content.

Cretaceous and Tertiary sand and gravel in the extreme western part of the report area yield moderate to large supplies of water, although not as much as the Ohio River valley fill; yields of 200 gpm or more are often encountered. At present, the area is primarily devoted to agriculture, but as new industries move into the area and irrigation becomes more common, ground-water pumpage will be greatly increased.

Mississippian limestones are the most productive consolidated rock aquifers within the study area. Large springs issuing from these limestones are already being used by a number of small towns, and minimum flows of as much as 4.5 mgd are reported. In the Mammoth Cave area, the minimum flow of the largest spring is 1.2 mgd. The flow of the larger springs is highly variable, however, and the adjacent rock may be fairly impermeable, thus ruling out the possibility of large yields from wells. In addition, water in some areas tends to become saline at depths greater than 75 feet.

Pennsylvanian sandstones in the Western Coal Field region reportedly yield as much as 250 gpm to individual wells. These larger yields, however, are from wells ranging in depth from 150 to more than 600 feet. Ground-water yields adequate for domestic needs are generally available throughout the region.

The chief sources of ground water, in order of estimated decreasing potential, are as follows:

1. Alluvium along the Ohio River from Madison, Ind., to Cairo, Ill.

2. Sand and gravel of Cretaceous and Tertiary age along the western edge of the report area.

3. Limestones of Mississippian age in the Plateau region.

4. Sandstones of Pennsylvanian age, especially along the western side of the Western Coal Field region.

5. Alluvium in major tributary valleys to the Ohio River, especially along the lower Green River.

PHYSIOGRAPHY AND DRAINAGE

Physiographically, the Lower Ohio River drainage area, as covered by this report, includes the Blue Grass, Western Coal Field, Mississippian Plateau, and Jackson Purchase regions in Kentucky, and part of the great glaciated Till Plains in Indiana and Illinois. The physiography and geology differ from one region to another and hence ground-water conditions are different in each region.

Large areas of the Mississippian Plateau are almost completely lacking in small surface streams; the principal drainage is underground. As the name indicates, coal mining is an important industry in the Western Coal Field region of Kentucky and adjacent areas underlain by the same coal-bearing formations in Indiana and Illinois.

The total area described in this report is about 19,000 square miles, and is drained by a 432-mile reach of the Ohio River between Madison, Ind., and Cairo, Ill. Major tributaries in the area are the Salt, Green and Tradewater Rivers in Kentucky, Blue River in Indiana, and the Saline and Cache Rivers in Illinois. The Salt River rises in Boyle County in the Blue Grass region and flows northward across rocks of Ordovician age to Anderson County where it swings westward and crosses the Mississippian Plateau to the Ohio River. The Green River rises in Lincoln County in the Mississippian Plateau and flows westward across Mississippian rocks to Butler County where it crosses into Pennsylvanian rocks in the Western Coal Field region, and then flows northwestward across these rocks to its junction with the Ohio River near Evansville. The Tradewater River rises in Mississippian rocks of the Mississippian Plateau in Christian County, but crosses into Pennsylvanian rocks of the Western Coal Field region and continues northward to its junction with the Ohio River at Caseyville. The Blue, Saline, and Cache Rivers all rise in the glaciated Till Plains Section north of the Ohio River. These streams were the spillways for the glacial melt waters of the ice age, and consequently their valleys contain unconsolidated sand and gravel deposits.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

Glacial deposits cover the extreme northeastern and northwestern portions of the Lower Ohio River drainage area in eastern Indiana and Illinois (pl. 22). These deposits are only a few feet to 20 feet in thickness, and provide small yields of water to shallow dug wells in the area.

The most important sources of ground water in the report area are the outwash and alluvial deposits in the valley of the Ohio River. These deposits range in width from about one mile near Madison, to more than 10 miles near Owensboro, and in thickness from about 90 to 150 feet. Practically everywhere along the valley, fine-grained sediments deposited by the Ohio River in the post-glacial period cover coarser glacial sediments. These fine-grained deposits are as much as 75 feet thick, but their average thickness is only about 25 feet.

The upper fine-grained deposits do not supply large amounts of water to individual wells because movement through them is slow. However, these deposits are not so impermeable as to preclude some downward percolation, and when their entire area is considered, large quantities of water pass through to the underlying sands and gravels. In some places, erosion by the river itself has exposed the coarse-grained sand and gravel under the river bed, thus permitting water to readily move from the river into the underlying material. This method of recharging the underlying aquifers makes possible continued large withdrawals of ground water such as at Louisville.

The coarse-grained materials extend across the entire width of the valley. Generally the coarsest material is near the base of the old deep river channel. At Louisville and Owensboro, cobbles up to 8 inches in diameter are reported and much of the material is more than 2½ inches in diameter. At Paducah, cobbles up to 3 inches are reported, but most of the material is reported as "pea gravel", having an average diameter of about ¼ inch.

From Louisville to near Kosmosdale, at the Jefferson-Bullitt County line, the valley is as much as 5 miles in width. This is the most heavily developed ground-water area in the entire area of this report. During World War II, industrial pumpage of ground water reached 62 mgd.

From Louisville to Hawesville, the river valley averages about 1½ miles in width, and the glacial and alluvial sediments are about 150 feet thick. Individual wells along this stretch of the river reportedly yield up to 800 gpm. From Hawesville to just south of Shawneetown, the valley is much wider and individual wells reportedly yield as much as 1,500 gpm of water. Large diameter collectors at Henderson were rated at 9,000, 5,000, and 3,500 gpm, when constructed in 1942, although their yields have since declined.

An old abandoned channel of the Ohio River lies north of the present river and extends from about Golconda to just north of Cairo (pl. 22). This old channel is more than 180 feet deep and is filled with fairly permeable layers of sand and gravel. Little data are available concerning the hydraulic characteristics of these deposits, but because of the absence of a surface stream to recharge the deposits, the sustained yield to wells would undoubtedly be less than in the valleys of the present-day streams. Wells drilled into these deposits range from 40 to 180 feet in depth, and yield as much as 300 gpm.

Unconsolidated sediments in the valleys of streams tributary to the Ohio River also are sources of water supply in various localities, although the overall potential for development of water from these sources does not rival the potential from the Ohio River alluvium. The glacial and alluvial deposits underlying the Cache River are fairly extensive and are probably open to recharge from the overlying river. The deposits are as much as 150 feet thick, and one well at Ullin reportedly yielded 300 gpm. There are also small deposits of alluvium and outwash along the Blue River, but data are scarce as to lithology, thickness, and yields of these deposits.

Extensive deposits of alluvium are present along the Green River. Along the lower Green River, wells used for waterflooding of oil formations obtained about 300 gpm from these deposits. A well 57 feet deep yielded 440 gpm from the Green River alluvium during construction of the lock and dam at Spottsville, Ky. Most wells are of the shallow dug or driven type and supply only enough water for domestic use. The largest reported withdrawal of ground water, 1,000 gpm, is obtained near the confluence of the Green River and the Ohio River, and undoubtedly reflects the influence of the fill in the valley of the Ohio River.

Water in the unconsolidated deposits along the Ohio River is very hard, ranging from 200 to 600 mg/l (table 11). The water also has objectionable concentrations of iron. An analysis of a water sample taken from the alluvium along the Green River had a hardness of 130, an iron content of 0.3 mg/l, and negligible concentrations of sulfate and chloride. Water samples taken from the alluvium and outwash underlying the Cache River show the water to be hard, and to have fairly large concentrations of iron.

TABLE 11.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE LOWER OHIO RIVER DRAINAGE AREA.

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (^{o}F)
Unconsolidated Sediments										
Glacial and alluvial sand and gravel in the Ohio River valley	0-120	100-1,500	40-120	5-50	150-600	5-50	5-30	.2-3.5	200-900	---
Glacial and alluvial sands along former course of Ohio River, between Golconda and Ullin, Ill.	---	100-300	40-180	---	90-370	75-200	5-20	.2-3.0	170-500	58
Alluvial deposits in the valley of the lower Green River	100	300	100	30	130	10	12	0.3	---	---
Bedrock Formations										
Sand and gravel of the Tertiary and Cretaceous Systems	---	40-600	400-1000	---	150-300	5-25	5-75	.1-5.0	200-350	59
Sandstones of the Pennsylvanian System	---	20-150	50-900	---	50-450	25-250	5-75	---	200-2100	59
Limestones of the Mississippian System	---	30-300 (springs 100-50,000)	200-650	---	---	---	---	---	---	---

Bedrock Formations

The area covered by this report is underlain by gently dipping Paleozoic rocks that form a shallow basin extending into southern Illinois. Because of the gentle dip of the rocks, they outcrop in wide bands across the basin with the youngest rocks of Pennsylvanian age in the center of the basin. Included in the bedrock systems are strata of limestone, sandstone, and shale. In the western part of the report area, the consolidated Paleozoic rocks are overlain by unconsolidated deposits of Cretaceous and Tertiary age. These deposits dip gently westward.

In the northeastern corner of the basin, rocks of Ordovician, Silurian, and Devonian age crop out at the surface. The Ordovician rocks are mostly limestone with numerous shale partings. Wells drilled into the limestone beds may yield adequate supplies of water for domestic use, and near Perryville, Ky., two wells, 92 and 96 feet deep, reportedly yield 50 gpm each. The Silurian rocks, predominantly limestone and dolomite interbedded with shale, are about 250 feet thick. The Devonian rocks are mostly shale, and in the eastern part of the report area are about 50 feet thick. Rocks of both the Silurian and Devonian Systems are poor sources of water for other than domestic needs; water from the Devonian shales is in many places highly mineralized.

Mississippian rocks crop out in rather broad bands along the eastern and southern parts of the report area. The area is a part of the Mississippian Plateau region and is characterized by rather low relief. The rocks range in thickness from about 350 feet in the east to more than 1,000 feet along the southern and western parts of the basin. The Mississippian rocks are mostly limestone but include some sandstone and shale, especially in the eastern part of the area. Large areas are characterized by the lack of small surface streams. In such areas, most of the drainage is underground; Mammoth Cave is within this area of cavernous limestones.

Although large areas within the Plateau are underlain by cavernous limestones, the limestone is not so productive of ground water as may be imagined. The water in the caverns tends to drain out during dry periods, and the limestone itself is not very permeable. Also, saline water in some places becomes a problem at depths greater than 75 feet. Many springs reportedly flow at rates up to 1 mgd, and springs near Mammoth Cave reportedly have minimum flows of as much as 1.25 mgd. Many towns obtain their water supply from springs in the Mississippian Plateau region.

Pennsylvanian rocks are largely sandstone and shale, and include beds of coal. The rocks range in thickness from about 500 feet in the southeast to about 3,000 feet in the northwest. In areas where the shales predominate, yields of wells are generally not sufficient for even domestic needs. The sandstones yield adequate supplies for domestic needs, and some industries and municipalities reportedly pump more than 200 gpm from the sandstone aquifers. Towns such as Drakesburg and St. Charles, Ky., reportedly pump as much as 250 gpm from individual wells ranging from 200 to more than 600 feet in depth.

Along the western edge of the report area, between the mouth of the Tennessee River and the confluence of the Ohio and Mississippi Rivers, is a small area of unconsolidated Cretaceous and Tertiary sand and gravel. The sand and gravel deposits commonly yield more than 100 gpm, and reportedly yield as much as 800 gpm of water. The chemical quality of water from these deposits is excellent, and the water is not as hard as water from the Ohio River valley fill.

CURRENT STATUS OF GROUND-WATER INFORMATION

All the report area is covered by some form of generalized hydrologic reconnaissance-type reports on ground-water resources. The portion of the report area north of the Ohio River is covered by state reports which contain information valuable in the interpretation of ground-water resources in the southern parts of Indiana and Illinois. The area in Kentucky is covered by ground-water reconnaissance reports and ground-water availability maps (Hydrologic Atlases) for the Blue Grass region, Western Coal Field region, Mississippian Plateau, and Jackson Purchase region. Considerable detailed information on the hydrology of the alluvial deposits in the Louisville area is available and is included in 23 published reports. Information concerning the hydrologic characteristics of the alluvial deposits in the major tributary valleys of the report area, however, are completely inadequate for even general planning purposes.

Bibliographic citations for the chief published reports on ground-water availability, for areas of county-size or larger, are as follows:

Brown, R.F., and Lambert, T.W., 1962, Availability of ground water in Allen, Barren, Edmonson, Green, Hart, Logan, Metcalfe, Monroe, Simpson, and Warren Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-32.

_____ 1963, Availability of ground water in Breckinridge, Grayson, Hardin, Larue, and Meade Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv.Atlas HA-33.

_____ 1963, Reconnaissance of ground-water resources in the Mississippian Plateau region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1603, 58 p., 16 pls.

Devaul, R.W., and Maxwell, B.W., 1962, Availability of ground water in McLean and Muhlenburg Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-29.

Illinois State Water Survey, 1962, Potential water resources of southern Illinois: Rept. Inv. 31, 97 p.

Indiana Water Resources Study Committee, 1956, Indiana water resources, technical appendix: 127 p.

Lambert, T.W., and Brown, R.F., 1963, Availability of ground water in Adair, Casey, Clinton, Cumberland, Pulaski, Russell, Taylor, and Wayne Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-35.

Maxwell, B.W., and Devaul, R.W., 1962, Availability of ground water in Butler and Ohio Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-26.

_____ 1962, Availability of ground water in Hopkins and Webster Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-30.

_____ 1962, Availability of ground water in Union and Henderson Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-28.

_____ 1962, Reconnaissance of ground-water resources in Western Coal Field region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1599, 34 p., 3 pls.

Palmquist, W.N., Jr., and Hall, F.R., 1960, Availability of ground water in Boyle, Garrard, Lincoln, and Mercer Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-20.

_____ 1961, Reconnaissance of ground-water resources in the Blue Grass region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1533, 39 p.

Pryor, W.A., 1956, Groundwater geology in southern Illinois, a preliminary geologic report: Illinois State Geol. Survey Circ. 212, 25 p.

Walker, E.H., 1957, The deep channel and alluvial deposits of the Ohio valley in Kentucky: U.S. Geol. Survey Water-Supply Paper 1411, 25 p., 6 pls.

Ground water in the glacial and alluvial sediments along the Ohio River in Kentucky is covered in detail by the following series of hydrologic atlases entitled "Geology and hydrology of alluvial deposits along the Ohio River":

Author	Hydrologic Atlas No.	Area
Gallaher, J.T.	72	Hawesville and Cloverport
____	74	Lewisport and Owensboro
____	91	Henderson
____	96	Spottsville and Reed
____	95	Between Wolf Cr. and West Point
Price, W.E.	97	Between Ethridge and the Twelvemile Island
Gallaher, J.T.	110	Stanley
Price, W.E.	111	Between southwestern Louisville and West Point
Gallaher, J.T.	129	Between Uniontown and Wickliffe

MANAGEMENT CONSIDERATIONS

This study reveals that there are large supplies of ground water available from the glacial and alluvial deposits along the Ohio River between Madison, Ind., and Cairo, Ill., and also fairly large yields available from the unconsolidated Cretaceous and Tertiary sand and gravel in the western portion of the basin. Water from the Ohio valley fill generally is hard, has excessive amounts of iron, and undoubtedly would require treatment before it would be satisfactory for many uses. In addition, since the major source of recharge to the aquifer is the Ohio River, pollution of the river by industrial wastes compounds treatment problems of the ground water. The full potential of the valley-fill aquifers, therefore, cannot be realized unless the programs for pollution abatement and quality control of the surface water resources of the Ohio River basin are successful.

Detailed hydrologic studies are underway to provide a basis for future development of the Cretaceous and Tertiary sand and gravel. The area is primarily devoted to agriculture, but will undoubtedly be called on to meet anticipated future industrial demands and increased crop irrigation.

The construction of new navigational facilities on the Chio River should also be studied to determine the hydrologic effects on the underlying deposits. These studies should determine the effect of sediment transportation and deposition on recharge rates and also changes in quality of the recharge water.

In addition to the large quantities of water available from the sand and gravel deposits, there is some potential for development from limestone of Mississippian age and sandstones of Pennsylvanian age. The limestones have locally provided fairly large supplies of water to a number of towns within the drainage basin. However, a problem, which was severe in the past but is now being alleviated, is contamination of these supplies by oil field brines. Also, in limestone aquifers of this type, the danger of contamination from sewage and other waste disposal is always present. In these aquifers, the quality problems that are encountered are the same as those from surface-water sources, and the treatment required will be similar to that needed for surface sources of supply.

More information is needed on the principles of limestone hydrology so as to improve the chances of a successful well. The sandstones of Pennsylvanian age also need more study to better correlate the water-bearing strata, and to delineate areas where water draining from abandoned coal mines is contaminating streams and adjacent ground-water supplies.

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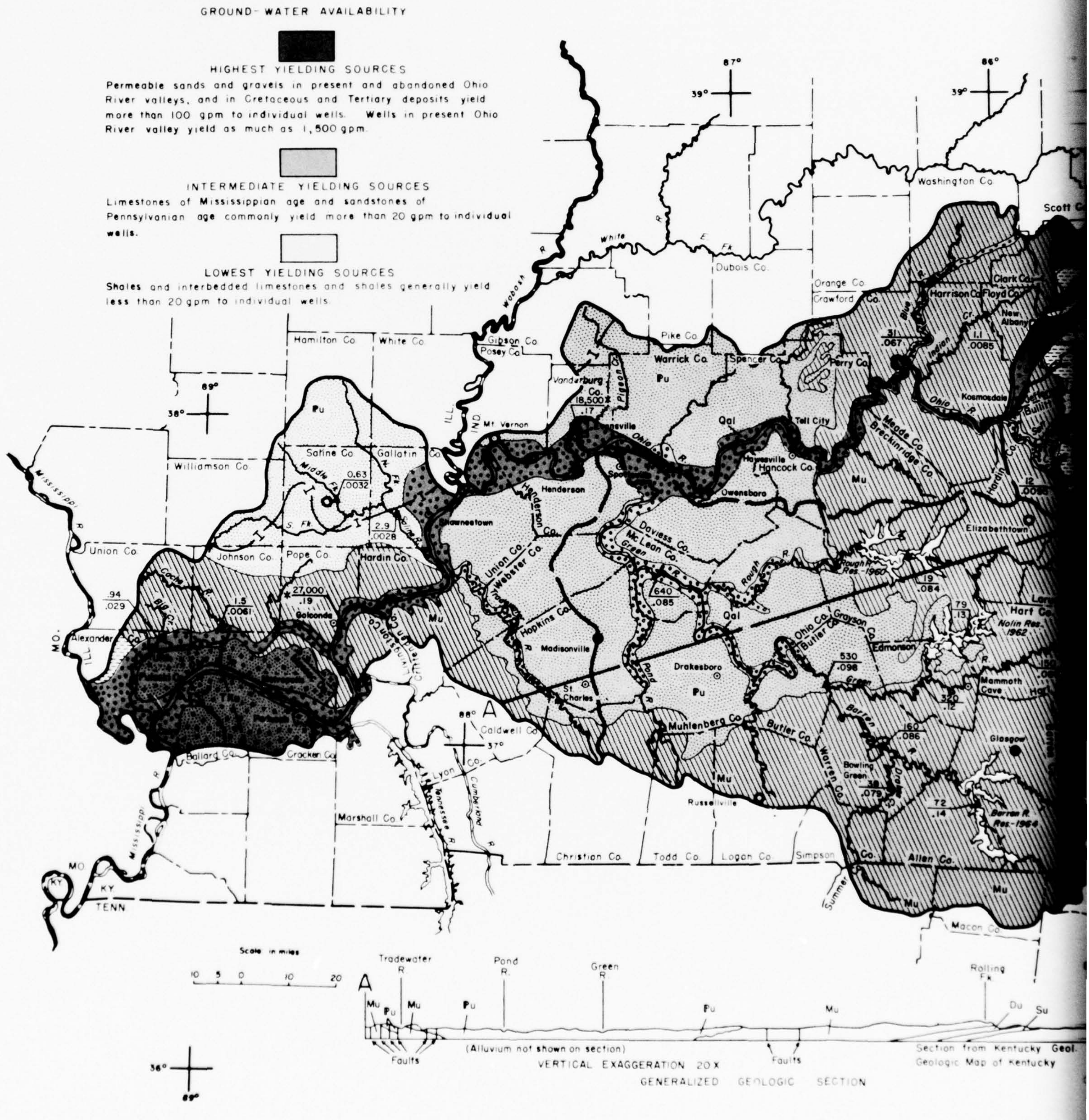
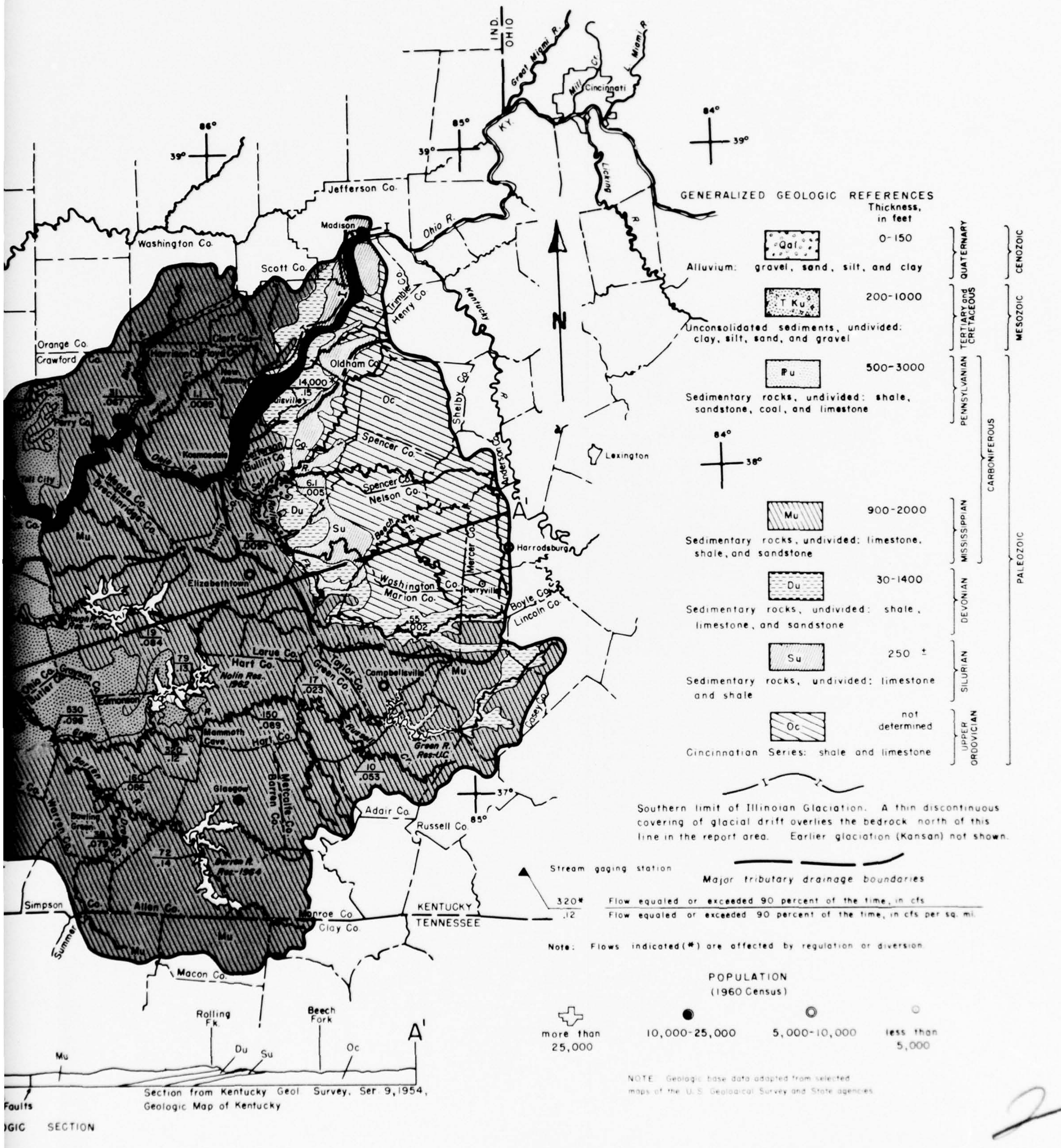




LOWER OHIO RIVER DRAINAGE AREA
SOURCES OF GROUND WATER

PLATE 22

Preliminary Survey
of
GROUND-WATER DISTRIBUTION AND POTENTIAL
in the
OHIO RIVER BASIN

Sub-drainage Area 12

CUMBERLAND RIVER BASIN

By

Paul R. Jordan

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
Mid-Continent Area

CUMBERLAND RIVER BASIN

CONCLUSIONS

The Cumberland River basin has less potential for future ground-water development than the other sub-areas of the Ohio River basin. Most of the highest-yielding sources, the large springs issuing from the Mississippian limestones, are already being used so are not available for future development. Ground-water yields adequate for small industrial and municipal supplies, however, are available in large areas of the basin.

The chief sources of ground water, in order of estimated decreasing potential, are as follows:

1. Limestones of the Mississippian System in the western Highland Rim physiographic section.

2. Limestones of the Mississippian System in the eastern Highland Rim physiographic section.

3. Sandstones of the Pottsville Formation in the Appalachian Plateau.

4. Sand and gravel in alluvium along the Cumberland River and the lower portions of the major tributaries.

The above ground-water sources generally yield water of a quality suitable for most uses with moderate or little treatment. Treatment for removal of iron would be desirable for nearly all the ground water.

PHYSIOGRAPHY AND DRAINAGE

From its headwater in southeastern Kentucky to its confluence with the Ohio River a few miles upstream from Paducah, the Cumberland River is more than 700 miles long and drains nearly 18,000 square miles. Poor Fork, the headwater stream, rises about 15 miles north of Big Stone Gap, Virginia, and flows westward on the Appalachian Plateau. The Kentucky-Virginia State line follows the divide between the Cumberland and Tennessee River basins and also between the Appalachian Plateau and the Valley and Ridge physiographic provinces. Two major tributaries, Rockcastle River and South Fork Cumberland River, also flow on the Appalachian Plateau, which is referred to as the Eastern Coal Field region in Kentucky. The shale and sandstone bedrock of the Plateau has been partly dissected by the streams, which are generally incised about 300 to 600 feet below the levels of the hilltops.

Near the mouths of the Rockcastle and South Fork Cumberland Rivers, the Cumberland enters the eastern Highland Rim section of the Interior Low Plateaus and also an upper finger of Lake Cumberland, formed by Wolf Creek Dam. The eastern Highland Rim is about 1,000 feet lower than the Appalachian Plateau, and the escarpment delineating the two physiographic regions is rather distinct along most of the boundary. Limestone and a little shale and sandstone form most of the eastern Highland Rim, which has moderately sloping to hilly topography with many small sinks on the uplands and many small springs on the valley sides and bottoms. Dale Hollow Reservoir, occupying the Obey River valley along the Kentucky-Tennessee State line, and Center Hill Reservoir and other major parts of the Caney Fork drainage system, also are in the eastern Highland Rim section.

Between the mouths of the Obey River and Caney Fork, the Cumberland River enters the Nashville Basin, which has the geologic structure of a dome, but in which erosion of the surface has produced a broad, shallow topographic basin. Caney Fork below Center Hill Dam, the entire Stones River, and the upper half of Harpeth River are in the Nashville Basin, which extends westward a short distance past Nashville. The Nashville Basin is composed mostly of limestone, as is the Highland Rim, and the boundary between the two is not distinct. The topography of the Nashville Basin is moderately sloping to hilly, but sinks and springs are not common. Old Hickory Lake occupies much of the length of the Cumberland River valley in this section. J. Percy Priest Dam is under construction on Stones River a few miles east of Nashville.

From near Nashville to its mouth near Paducah, the Cumberland River is in the western Highland Rim physiographic section. This section is similar in topography to the eastern Highland Rim, is composed of the same types of rocks, but has more and larger sinks and springs. The lower half of Harpeth River and all of the Red River, which enters the Cumberland at Clarksville, are in this section. Cheatham Lake extends for several miles down the Cumberland from Nashville to its dam, and Barkley Dam, now under construction adjacent to the Tennessee River's Kentucky Dam, will create a lake extending upstream as far as Clarksville.

SOURCES AND DISTRIBUTION OF GROUND WATER

Unconsolidated Sediments

River alluvium extends along the Cumberland River and its major tributaries for most of their lengths. Although this alluvium undoubtedly contributes large quantities of water to the rivers to sustain their flows during dry weather, virtually no direct use is made of ground water in the alluvium by pumping from wells or collectors. Basic reasons for this lack of use are frequent inundation of the floodplain and the availability of good-quality water from the river. No information is available about water wells in the alluvium, but borings and seismic measurements by the Corps of Engineers at potential dam sites show the approximate thickness and general character of the alluvial sediment.

From the mouth of the Cumberland River upstream to near Clarksville the alluvium ranges from about 50 to 120 feet in thickness. From near Clarksville upstream at least as far as Carthage, it is about 30 to 60 feet thick. The upper part of the alluvium consists of silt and clay, but in some places it is sandy. The lower part consists mainly of silt and sand, commonly increasing in coarseness toward the bottom. Overlying the bedrock in much of the valley are lenses of sandy gravel that probably could yield 20 to 50 gpm of ground water. The low permeability of the overlying silt and clay reduces the rate of infiltration to the basal gravel, but the recharge area is large so the total amount of recharge could be significant.

In a small upland area between the Cumberland and Tennessee Rivers near Kentucky Lake, the Mississippian rocks are overlain by discontinuous deposits of clay, sand, and gravel of the Cretaceous System. Although conclusive data are lacking, the gravel in this area is probably too thin to be a source of large or dependable ground-water supplies.

Bedrock Formations

The headwaters of the Cumberland River, on the Appalachian Plateau, are underlain by the Pottsville Formation of Pennsylvanian age (pl. 23). This formation also underlies the major upstream tributaries, Rockcastle River and South Fork Cumberland River. It is composed principally of shale and sandstone interspersed with thin beds of coal, siltstone, and limestone.

The upper half of the Pottsville Formation contains more shale than sandstone and the latter generally is too fine-grained to transmit water freely. The lower half contains less shale and more coarse-grained, massive sandstone through which water can circulate. Shallow wells, intended only to satisfy domestic needs, yield only a few gallons per minute and in many cases less than one gallon per minute. Municipalities, industries, and institutions requiring larger supplies can, however, generally obtain yields of 20 to 100 gpm by drilling to near the bottom of the Pottsville. Wells adequate for municipal and industrial supplies are normally deeper than 150 feet, and depths of 300 feet are not uncommon. Static water levels are generally within 100 feet of land surface, even in the deeper wells. A few wells, such as an industrial well at Corbin, Ky., yield about 200 gpm, and a municipal well at Jellico in Campbell County, Tennessee, has been pumped at 375 gpm. Most industrial and municipal wells in the Pottsville Formation, however, have smaller yields. Rather typical is a well at Coalgood in Harlan County, Ky., that is 207 feet deep and yields 75 gpm.

Water from the Pottsville Formation generally meets the standards suggested by the U.S. Public Health Service for the chemical quality of drinking water except that the iron content exceeds 0.3 mg/l and frequently exceeds 3 mg/l; therefore, removal of iron is desirable for most uses of the water. The water normally has less than 120 mg/l of hardness, less than 60 mg/l of sulfate, and less than 20 mg/l of chloride (table 12). Despite the coal beds contained in the Pottsville and the many abandoned coal mines from which acidic water drains to the streams, only one of 12 ground-water analyses showed a pH of less than 6.7.

TABLE 12.--GENERAL HYDROLOGIC AND CHEMICAL CHARACTERISTICS OF THE CHIEF AQUIFERS OF THE CUMBERLAND RIVER BASIN

(Numerical ranges represent typical values and do not include unusually high or low values.)

Source	Thickness (ft)	Yields of high-capacity wells (gpm)	Well depths (ft)	Depths to water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total dissolved solids (mg/l)	Temp. (^{o}F)
Limestones of Mississippian System on western Highland Rim	----	20-100	80-250	30-100	180-400	10-200	3-100	.2-1.0	250-500	55-60
Limestones of Mississippian System on eastern Highland Rim	----	20-100	60-100	20-50	50-200	10-50	2-20	.2-5	200-400	55-60
Sandstones and conglomerates in lower part of Pottsville Formation	----	20-100	150-300	10-100	40-120	5-60	5-20	.4-6	----	58-65
Basal sand and gravel in alluvium along Cumberland River and downstream parts of major tributaries	3-10	20-50[a]	50-120[b]	10-30[b]	----	----	----	----	----	----

[a] No yield data available; inferred from sparse information on thickness and character of sediments.
[b] Estimated from related information.

From the extreme eastern tip of the Cumberland River basin to a few miles west of La Follette, Tenn., rocks of the Mississippian System are exposed in a narrow band by the Pine Mountain thrust fault. These rocks are nearly untested for potential large yields of ground water, but the possibility of yields large enough for municipal or industrial supplies is shown by a municipal well at Pineville in Bell County, Ky., that was reported to be 110 feet deep and to yield 500 gpm. The large yield is associated with abundant fracturing in the vicinity of the thrust fault.

The Cumberland River enters the eastern Highland Rim physiographic section near the mouths of Rockcastle River and South Fork Cumberland River and receives dry-weather flow from limestones of the Mississippian System. (The Devonian and Silurian rocks (pl. 23) are found only in a narrow band adjacent to the Ordovician System.) Several of the rock formations of the Mississippian System have been deeply weathered. The thickness of the weathered zone exceeds 100 feet at the tops of many hills. This overburden is a source of water for domestic supplies, and many wells drilled into the consolidated bedrock have their casings slotted to receive water from the overburden. A large share of the dry-weather flow of streams in the Caney Fork and Obey River basins is also contributed by flow from the overburden. The consolidated Mississippian rocks are extensively fractured and jointed and have many solution channels, both large and small. A large number of springs issue from the solution openings and provide water supplies for many towns. Flows of more than 100 gpm from springs are common, and springs having multiple openings have yields as high as the 2,600 gpm flow of a spring located east of Center Hill Reservoir.

Yields of wells in the eastern Highland Rim do not reach the magnitude of the large springs, but wells that chance to penetrate several solution channels yield as much as 500 gpm. Most wells encounter fewer openings in the rock, however, and yield between 20 and 100 gpm, although some dry holes have been reported. Yields of wells in this area are nearly unpredictable, but they are shown in the 20 to 100 gpm class on plate 23 because more than 20 gpm can be obtained at nearly all locations within the area, although in a few cases only after one or more test holes are drilled. The sparse data on the depths of wells and depths to water suggest that any significant yields of water will be encountered at depths of less than 100 feet and that the water level will probably be between 20 and 50 feet below land surface.

A few chemical analyses of water from springs and wells in the carbonate rocks of the eastern Highland Rim indicate that the water ranges in hardness from 50 to 200 mg/l, has negligible amounts of sulfate and chloride, and has less than 400 mg/l of dissolved solids, but is likely to have more than 0.3 mg/l and occasionally as much as 5 mg/l of iron. Saline water associated with oil is commonly encountered at a depth of about 150 feet below the level of the major drainage.

Ordovician rocks form the floor of the Nashville Basin, in which the Cumberland River flows between Jackson County and Nashville, Tenn. Stones River lies entirely within the Nashville Basin and receives its dry-weather flow from the Ordovician limestones and from alluvium. These limestones do not have numerous solution channels such as those found in the Mississippian rocks; therefore, very few large springs are present. Unusually high yields of ground water are found at a few places such as Eagleville, Tenn., near the headwater of the Harpeth River, where a municipal well yields 100 gpm, but at most places the yield of ground water is barely more than adequate for domestic needs. So many dry holes have been reported that the Ordovician rocks are shown in the category of yielding less than 20 gpm on plate 23.

The Cumberland River basin downstream from Nashville is in the western Highland Rim physiographic section which is underlain by the same formations as the eastern Highland Rim. Deep weathering has produced an overburden that supplies water to many domestic wells. Springs issuing from the unweathered limestone are plentiful and supply the water needs of many towns such as Cadiz in Trigg County, Ky., Erin in Houston County, Tenn., and Guthrie in Todd County, Ky. Springs also constitute most of the water supply for Princeton, Ky. Minimum flows of springs used for public supplies range from about 200 gpm at Erin, Tenn., to about 2,500 gpm at Cadiz, Ky.; thousands of smaller springs are also present and are used for household supplies, stock watering, and to satisfy many other needs.

Wells in the Mississippian rocks of the western Highland Rim supply a number of towns, industries, and institutions. Depths and yields of wells vary greatly, but yields of 20 to 100 gpm seem to be available to wells 80 to 250 feet deep almost anywhere in the area. Very few dry holes have been reported. Nearly all reported depths to water were between 30 and 100 feet. A fairly typical well in the western Highland Rim section is a municipal well at Dover in Stewart County, Tenn., that is 220 feet deep and yields 60 gpm. Depth to water was reported to be 80 feet. Several wells yield as much as the 150 gpm of an industrial well 125 feet deep at Princeton, Ky., but yields

this high cannot be expected from Mississippian rocks in most areas. A few wells are more than 300 feet deep; for example, an industrial well in Dickson County, Tenn. is 427 feet deep and yields 25 gpm, but it is likely that very little extra yield was gained from the additional depth.

Ground water from rocks of the Mississippian System in the western Highland Rim seems to be harder and to contain less iron than ground water from the same rock system in the eastern Highland Rim, but the data are not conclusive. Hardness in all but one of the analyses inspected was more than 180 mg/l, but only one analysis showed more than 1 mg/l of iron. Many samples, however, had more than the recommended iron limit of 0.3 mg/l. Dissolved solids content is normally less than 500 mg/l, and chloride is well below the limit of 250 mg/l for drinking water recommended by the Public Health Service. Sulfate in a few of the samples approached, but did not exceed, the 250 mg/l limit. Saline water associated with oil is commonly encountered at a depth of about 200 feet below the level of the major drainage.

CURRENT STATUS OF GROUND-WATER INFORMATION

The Cumberland River basin is entirely covered by broad, reconnaissance-type reports on ground water, but none of the area is covered by detailed reports. The area in Kentucky is covered by reconnaissance reports on the Eastern Coal Field region (Appalachian Plateau) and on the Mississippian Plateau region (Highland Rim), and by maps of the Hydrologic Atlas series. The area in Tennessee is covered by reconnaissance reports on the Cumberland Plateau (Appalachian Plateau), Highland Rim, and Central Basin (Nashville Basin).

Bibliographic citations for the chief areal reports on ground-water availability for areas of county-size or larger are as follows (a report limited to home supplies is not included):

Brown, R.F., and Lambert, T.W., 1962, Availability of ground water in Allen, Barren, Edmonson, Green, Hart, Logan, Metcalfe, Monroe, Simpson, and Warren Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-32.

_____ 1963, Reconnaissance of ground-water resources in the Mississippian Plateau region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1603, 58 p., 16 pls.

Hendrickson, G.E., 1958, Summary of occurrence of ground water in Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-10.

Kilburn, Chabot, Price, W.E., Jr., and Mull, D.S., 1962, Availability of ground water in Bell, Clay, Jackson, Knox, Laurel, Leslie, McCreary, Owsley, Rockcastle, and Whitley Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-38.

Kirkpatrick, G.A., Price, W.E., Jr., and Madison, R.J., 1963, Water resources of eastern Kentucky - Progress report: Kentucky Geol. Survey, ser. 10, Rept. Inv. 5, 67 p., 10 pls.

Lambert, T.W., and Brown, R.F., 1963a, Availability of ground water in Caldwell, Christian, Crittenden, Livingston, Lyon, Todd, and Trigg Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-34.

_____ 1963b, Availability of ground water in Adair, Casey, Clinton, Cumberland, Pulaski, Russell, Taylor, and Wayne Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-35.

Moore, G.K., and Bingham, R.H., 1965, The availability of ground water in the western Highland Rim of Tennessee: Tennessee Acad. Sci. Bull., v. 40, no. 1, 5 p., 3 figs.

Newcome, Roy, Jr., 1958, Ground water in the central basin of Tennessee: Tennessee Div. Geol., Rept. of Inv. No. 4, 81 p.

Newcome, Roy, Jr., and Smith, Ollie, Jr., 1958, Ground-water resources of the Cumberland Plateau in Tennessee: Tennessee Div. Water Resources, 72 p.

______ 1962, Geology and ground-water resources of the Knox Dolomite in middle Tennessee: Tennessee Div. Water Resources, Water Resources Series No. 4, 43 p.

Piper, A.M., 1933, Ground water in north-central Tennessee: U.S. Geol. Survey Water-Supply Paper 640, 238 p.

Price, W.E., Jr., Kilburn, Chabot, and Mull, D.S., 1962, Availability of ground water in Breathitt, Floyd, Harlan, Knott, Letcher, Martin, Magoffin, Perry, and Pike Counties, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-36.

Price, W.E., Jr., Mull, D.S., and Kilburn, Chabot, 1962, Reconnaissance of ground-water resources in the Eastern Coal Field region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1607, 56 p., 9 pls.

Smith, Ollie, Jr., 1962, Ground-water resources and municipal water supplies of the Highland Rim in Tennessee: Tennessee Div. Water Resources, Water Resources Series No. 3, 257 p.

MANAGEMENT CONSIDERATIONS

This study of ground water in the Cumberland River basin reveals that there are no aquifers that are capable of yielding large supplies (more than 100 gpm) of ground water to individual wells over large areas of the basin. A few wells in the Pottsville Formation on the Appalachian Plateau have high yields, but the need for ground water from that area has not been great enough to encourage widespread testing of the aquifer to delineate the areas of potentially high yield.

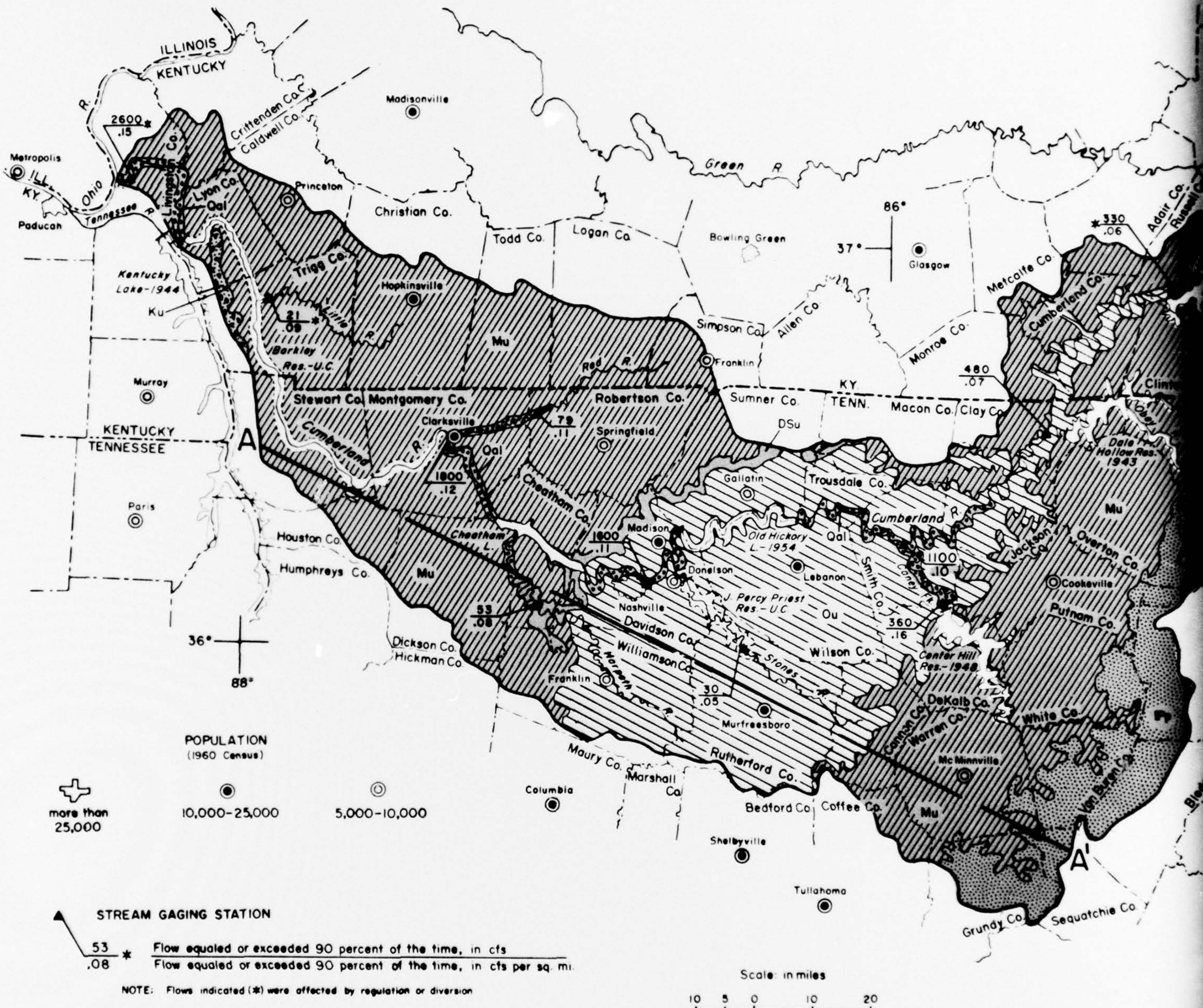
A few wells and a large number of springs in the limestones of the Mississippian System on the Highland Rim have yields of more than 100 gpm, and thus are adequate for municipal and industrial supplies. Future development of economical large ground-water supplies in this area will require careful study because nearly all of the largest and most economical sources, the springs, are already being used. Much ground water is available for further development, but because of the probability that many wells will have yields insufficient for water supply, ground-water development will be more costly than in most other drainage areas of the Ohio River basin. The natural quality of water from the limestone is generally good enough for most uses after moderate treatment, but danger of contamination always exists with limestone aquifers of this type. Development of this aquifer should be accompanied by study of the underground flow patterns and potential sources of contamination, and by monitoring of the changes in water quality.

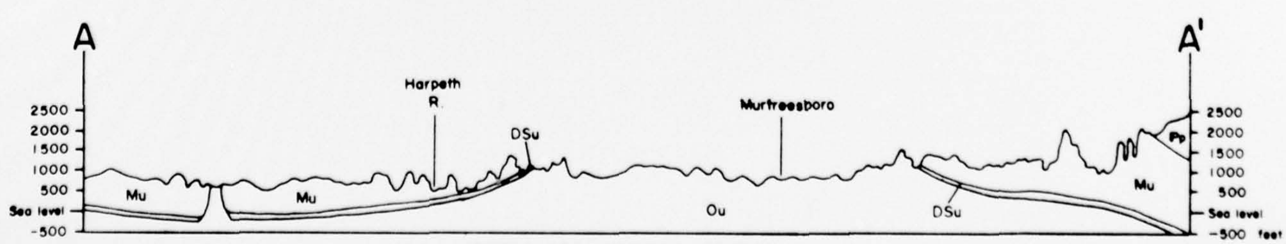
Some potential for future development of ground-water supplies from the alluvium along the Cumberland River and its major tributaries undoubtedly exists, but frequent inundation of the floodplain and the availability of good-quality water from the rivers may continue to discourage the use of this source of water, unless greatly increasing needs stimulate new developments.

Development of large ground-water supplies cannot be expected from the Ordovician limestones of the Nashville Basin. Even though high yields are obtained at two or three places, the chances of comparable yields in any other parts of the Ordovician rocks are very small. Unusually deep water wells can obtain only small additional yields (normally less than 20 gpm) from deep-lying formations of Cambrian and Ordovician age that do not crop out at the surface in the Cumberland River basin.

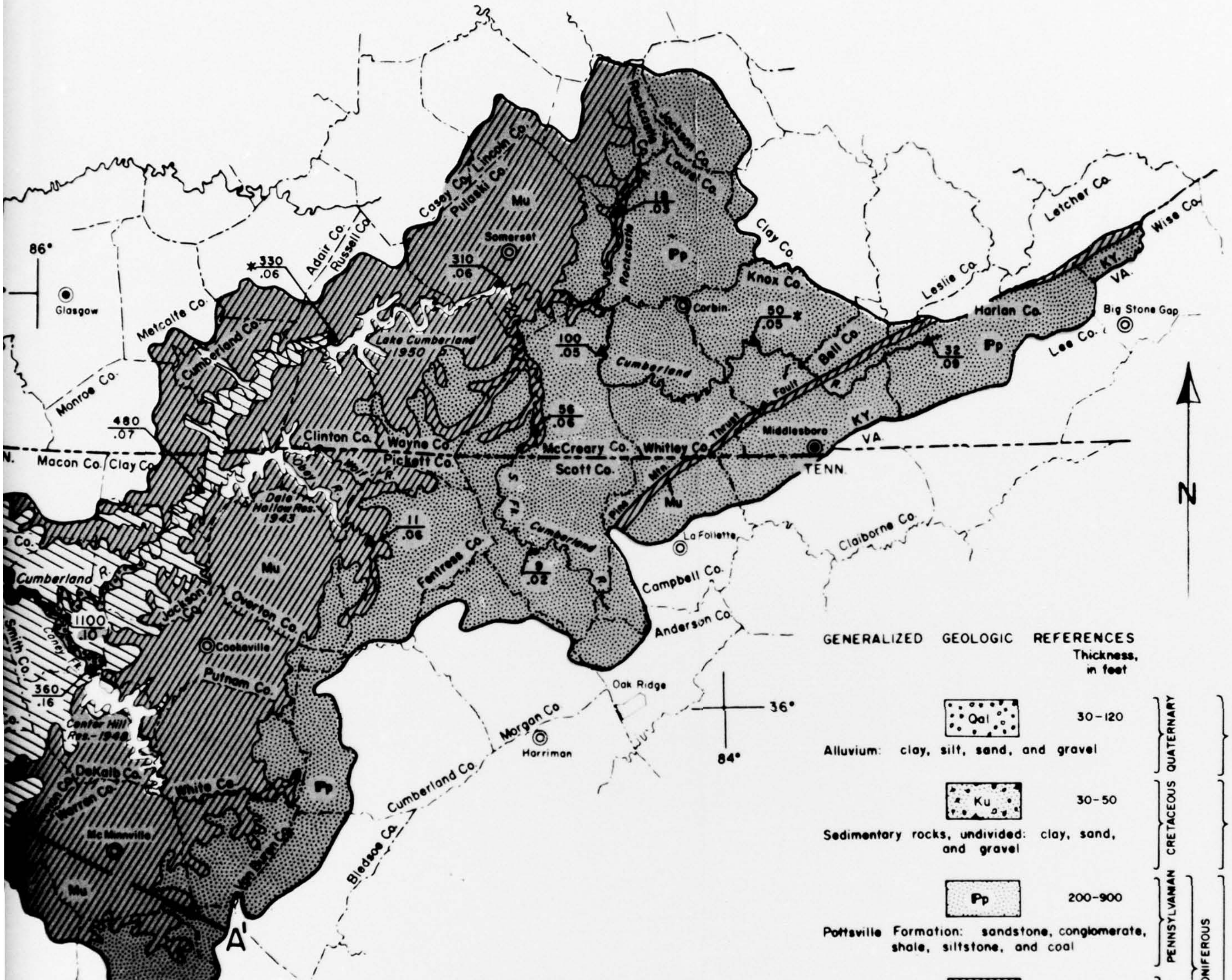
Although ground water can be found over large areas of the Cumberland basin, plentiful surface water and many favorable surface storage sites will favor the development of large multi-purpose reservoirs.

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY





GENERALIZED GEOLOGIC SECTION



GENERALIZED GEOLOGIC REFERENCES

	Thickness, in feet		
Qal — Alluvium: clay, silt, sand, and gravel	30-120	QUATERNARY	CENOZOIC
Ku — Sedimentary rocks, undivided: clay, sand, and gravel	30-50	CRETACEOUS	MESOZOIC
Pp — Pottsville Formation: sandstone, conglomerate, shale, siltstone, and coal	200-900	PENNSYLVANIAN	CARBONIFEROUS — PALEOZOIC
Mu — Sedimentary rocks, undivided: limestone, shale, and sandstone (Includes narrow bands of older rocks along Pine Mtn. Thrust Fault)	500-2000	MISSISSIPPIAN	CARBONIFEROUS — PALEOZOIC
DSu — Sedimentary rocks, undivided: shale and limestone (Shown only north and west of Nashville; elsewhere outcroppings form a band around underlying Ordovician rocks too narrow to map at this scale)	200-250	DEVONIAN and SILURIAN	PALEOZOIC
Ou — Sedimentary rocks, undivided: limestone and shale	not determined	ORDOVICIAN	PALEOZOIC

GROUND-WATER AVAILABILITY

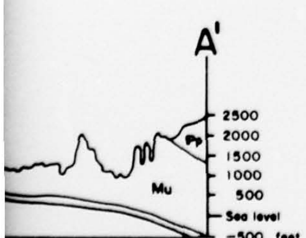
INTERMEDIATE YIELDING SOURCES

Mississippian limestones and Pennsylvanian sandstones commonly yield 20-100 gpm to individual high-capacity wells. A few wells yield more than 100 gpm. Gravel in the alluvium may be capable of yielding 20-50 gpm to individual wells.

LOWEST YIELDING SOURCES

Limestones in this area lack large or numerous secondary openings and generally yield less than 20 gpm to individual wells.

Note: No widespread aquifers in the Cumberland Basin consistently yield more than 100 gpm.



CUMBERLAND RIVER BASIN
SOURCES OF GROUND WATER

PLATE 23